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Effects of paraffin waxes on growth and physiology of rose plants

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EFFECTS OF PARAFFIN WAXES ON GROWTH AND PHYSIOLOGY OF ROSE PLANTS

by

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INTRODUCTION

Purpose of the Study

For more than twenty-five years it has been the practice of nurserymen to coat the canes of rose bushes by dipping them in melted paraffin wax. This is assumed to retard desiccation during transit and handling, thereby facilitating re-establishment after replanting.

Although many rose producers wax their roses, some of them do not. Most feel that the process is beneficial, but a few who do not wax feel that the benefits are insufficient to justify the cost, or in a few cases, that the wax may actually be detrimental. Evidence of the latter viewpoint appears in the introductory statements of papers by Foret (1951), Johnson and Janne (1954), and Lyle (1955).

In spite of the fact that the waxing of rose bushes is widely practiced, the process appears to have developed somewhat empirically. Until only recently (Johnson and Janne, 1954), little or no research work had been carried out to demonstrate the effectiveness of the waxing procedure. Even the principal effect of waxing, which is supposedly the reduction of moisture loss, had not been positively demonstrated.

The object of this study is to determine the effects of the types of paraffin waxes most commonly used on roses under conditions simulating those of commercial handling and replanting, and to study the physical and physiological effects of the waxes.

The Rose Plant Industry in the United States

As an indication of the importance of the rose plant as a nursery product in the United States, and therefore of the importance of this study, the following statistics are of interest.

During 1957[1], 40.9 million rose plants were produced and sold in the ten states of California, Colorado, Florida, Illinois, Iowa, Michigan, New York, Ohio, Oregon, and Texas. The wholesale value of these 40.9 million plants was reported as $13,236,800.

Although the data covered only ten states, these same ten states, according to the 1950 census produced about four-fifths of all the rose plants sold in the United States in 1949. On a proportional basis it is then estimated that about 50 million rose plants must have been produced and sold in 1957 in the United States, with a total wholesale value of about sixteen and one half million dollars.

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[1]United States Department of Agriculture. Agricultural Marketing Service, Crop Reporting Board. 1958. Nursery products, production and sales, 1957. Author. Washington, D.C.

LITERATURE REVIEW

Historical Development of Plant Waxing

Since the use of waxes on plants appears to have arisen empirically it would be useful to trace its origin. Like many another technical process or invention, the true origin of the application of wax or waxlike materials to plants is lost in antiquity.

As early as the first century A. D., Pliny[1] (Book 17, Chap. 24) describes the use of mud and chaff mixtures, powdered chalk and cow dung, and similar materials as protection for graft unions. This procedure apparently was not greatly improved upon for many centuries, for as late as 1825, Bliss, in his book The Fruit Grower's Instructor (pp. 7, 12, 13, 14) gives detailed instructions on the use of a loam and horse-dung mixture for covering grafts.

Besides the use of mud and chaff on grafts, Pliny[1] (Book 15, Chap. 18) also mentions the use of beeswax as a coating for apple and quince fruits to extend their keeping. Since the effect of both procedures is to minimize the drying out of the plant materials, it should not be surprising that someone subsequently thought of applying the wax to graft unions, a common practice today.

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[1]Plinius Secundus, C. 1855. The natural history of Pliny. Translated by John Bostock and H. T. Riley. H. G. Bohn, London.

The first reference to the use of wax on graft unions is obscure in the literature. However, as early as 1853, Barry, in his book The Fruit Garden (p. 77) describes the preparation and use of a "grafting composition" made up with rosin, beeswax, and tallow. Elliott, in a similar book (1854) titled The American Fruit-Grower's Guide, (p. 25), also describes "grafting wax" made up of rosin, beeswax, and lard. Both authors give detailed instructions for making up the mixtures and the techniques for applying them, as if they were old and commonplace procedures.

Both Barry and Elliott describe a wax mixture only, but it is interesting to note that Downing in 1871, in his book Downing's Selected Fruits for the Garden and Market (pp. 29-30), describes both a clay mixture and two wax mixtures. The clay mixture was made up of one third cow dung and two thirds clay, with a little hair added to prevent cracking. One of the wax mixtures was composed of pitch, beeswax, and cow dung and was meant to be applied in the melted state by brush. The other wax mixture was made up of tallow, beeswax, and resin. Although both clay and wax mixtures are described, the author states that "Grafting-wax is a much neater and more perfect protection than grafting-clay". Apparently this represents the era when the use of clay mixtures was beginning to be superseded by the more effective wax mixtures. Even today, however, the use of clay mixtures has apparently not been abandoned completely, for Garner (1947), in <u>The Grafter's Handbook</u> (pp. 76-77) describes grafting-clay, made of clay and cow dung with some chaffed hay or cow hair added to prevent cracking.

In the 1860's, about the time that beeswax-rosin-tallow mixtures were being developed, petroleum was discovered. One of the by-products in the early days of this new industry was a mixture of the heavy oil fractions with wax, which remained after the lighter fractions had been distilled off for illuminating purposes. According to Rumberger (1955), the greater portion of this early waxy stock was discarded. Later, however, with the development of industrial machinery, the heavier oils were separated for use as lubricants, leaving a more pure paraffin wax which began to reach the market in quantity about the beginning of the twentieth century.

With paraffin wax available, it was natural to try it as a grafting wax, since its properties were similar to beeswax and the other materials already being used. The first to test it appears to be Morris, who, in his book <u>Nut Growing</u>, in 1921 (p. 67) mentions dipping the cut ends of scions in melted paraffin before placement in storage. Although the use of paraffin wax appears to be new here, the process is not, as the very same procedure was described, using melted grafting wax, by Baker in 1866 in his book <u>Practical and Scientific Fruit Culture</u> (p. 368). Morris (p. 69) did, however, also experiment with covering scions completely with melted paraffin and found that this would keep them in good condition for several weeks without any other protection than a covering of dry sawdust.

Besides covering scion wood completely with melted paraffin, Morris also experimented with covering entire grafts with melted grafting wax or melted paraffin. He gives credit for the process, however, to a Mr. Jones and a Mr. Riehl as indicated in the following quotation from pages 93 and 94 of his book.

> The best step forward in grafting was one that I obtained from a pioneer in successful nut tree grafting, Mr. J. F. Jones, of Lancaster, Pennsylvania, who states that he obtained the method from Mr. E. A. Riehl of Godfrey, Illinois, the originator of the idea. This method consists in covering the entire graft, buds and all, with melted grafting wax. Buds when sprouting make their way through the hard grafting wax without any difficulty. The wax used by Mr. Jones contained lamp black, and that used by Mr. Riehl consisted of a beeswax and rosin mixture. It was found that these were successfully applicable in the north but not so freely farther south in the hotter sun. Examining into the reasons for this there seemed to be a probability that the black grafting wax of Mr. Jones and the brown or amber grafting wax of Mr. Riehl would naturally allow the heat ray from the sun to pass through to the graft while halting the actinic ray of light. The latter is extremely valuable for promoting the activity of bud chlorophyl, which acts only in the presence of light and in the best way in the best light. Furthermore, the heat rays would doubtless have certain destructive qualities at times. With this theoretical idea of the situation in mind I employed melted paraffin in place of the grafting wax, covering the scions, buds and all, as well as the mound in the stock and the wrapping, with translucent paraffin. This immediately proved to be a success.

In several very similar papers, Neilson (1928a, 1928b, 1929) described several experiences from which he concluded that coating of nursery stock with melted paraffin would be beneficial. Although not based on rigid scientific experiments by present-day standards his conclusions in the 1928a paper may be quoted in part as follows:

> In the case of the preservation of walnut scions, and with experiments in topworking and propagating fruit and nut trees, it has been found that parafine wax is positively one of the most valuable protective materials used so far. The work done in grafting fruit and nut trees has been under way for several years and includes hundreds of trees. The results, moreover, have been so uniformly successful where parafine wax was used and so unsatisfactory without its use that one is justified in the above statement. In view of the favorable results noted above and of the good effect which followed the use of parafine wax on newly planted trees, it would appear that this material is of decided value in preventing desiccation. The suggestion is therefore made that nurserymen at the time of digging try the effect of a thin coating of warm parafine to the trunks of trees or shrubs that are to be shipped long distances or which are difficult to transplant or carry over in storage. Fruit growers and others who plant deciduous trees or shrubs might also get better results by using parafine wax on plants that have not previously been waxed. The hot wax may be easily and quickly applied with a small paint brush after digging or before planting or one might plant the tree and apply the wax afterward. The cost of this treatment is very small indeed, being less than a cent a tree for the wax. In any case no injury is likely to occur and quite possibly good results would follow such treatment. If further trials show that parafine wax has definite value for the purposes outlined above, it would be desirable to devise some means of quickly waxing the trees in nurseries. In all probability this could be done by means of a deep vat wherein the trunks and tops of small trees or shrubs could be dipped in the hot wax and quickly withdrawn. The optimum temperature of the wax has not been definitely ascertained, but it is known that woody plant

> material can stand without injury a temperature of 160°F. It must be clearly understood that the trees should be immersed only for a moment - just dipped in the wax and then quickly withdrawn.

Although Neilson appears to have been the first to publish on the subject of coating the tops of nursery stock with melted paraffin, he was not the only one to have tried the procedure. Following the appearance of Neilson's articles, Willmann (1929) published his own observations on the process based on experiments with pecan trees. Some of Willmann's experiments were as early as the winter of 1925-1926, and he states:

> I have tried many different ways to protect the drying out of the newly set pecan tree, from the time it is planted until it has put out new growth. I wrapped some of the trees with paper, painted some with orange shellac and others with melted paraffin; and find paraffin the best.

Following the appearance of the first papers in 1928 by Neilson, many nurseries tried waxing various plants. In 1930 and 1931 Neilson published more papers in which he reported that surveys of nursery experience with waxing showed that results were generally favorable. In these, Neilson also gave complete recommendations for the waxing of various plants, particularly roses, and even included the approximate cost of waxing at that time.

By 1931, the process seems to have become an accepted nursery practice, for Laurie and Chadwick, in their book <u>The</u>

Modern Nursery, devote six pages (416 to 421) to describing the waxing of nursery stock.

Waxing even became the subject of a patent. Wilson (1933) was granted a patent on a wrapping method for nursery stock, the principal feature of which was the dipping of the plant tops in melted paraffin.

It appears then, that the waxing of plants on a commercial basis became established some time about 1930.

Studies on the Effects of Waxes on Plants

Probably the first experiment to be reported bearing directly on the waxing of rose bushes is that described by Neilson in 1928a:

> An interesting example of the effect of this wax on roses was observed on the property of Dr. J. M. Baldwin, of Bowmanville. Early in May, Dr. Baldwin planted a number of rose bushes which had been received in rather poor condition. From observation made on the effect of paraffin wax in protecting scions, Dr. Baldwin decided to experiment with paraffin wax on his rose bushes. Two of the plants were waxed and one left for comparison. The waxed bushes came out into leaf nicely and the unwaxed bush, like the unwaxed apple trees, made very little growth. The number of rose bushes under observation is rather small, but the results were very good and thus indicate what might be expected with a larger number of plants under similar conditions.

Tukey and Brase reported in 1931 the results of some experiments on various storage treatments of sweet cherry trees and roses. All material was stored in a concrete nursery cellar with a relative humidity of 93 to 95 per cent and a temperature varying between 33° and 45°F.

The treatments tried were various combinations of cording vs. trenching, pruning vs. not pruning, and coating with waxes vs. not coating. Waxing treatments were with paraffin, yellow crude scale wax, and cold miscible paraffin (Micol 180 and Micol 2015).

"Cording" consisted of laying the stock tightly together horizontally with their roots exposed and covered with moist excelsior. "Pruning" consisted of cutting back the tops 1/3 to 1/2 their length. "Trenching" consisted of setting the trees in damp sand to the depth they stood in the field. "Paraffining" and "waxing" consisted of dipping the tops in melted paraffin or wax maintained at a temperature of 175°F. The cold miscible paraffins were applied by two methods, with a brush or with a portable power paint sprayer.

Results with the sweet cherry trees indicated that as far as waxing was concerned there was no apparent benefit, and in fact there seemed to be some delay in subsequent growth. One of the cold miscible paraffins even seemed to be injurious.

With roses, the results indicated that generally the dipping in the melted waxes was beneficial, as measured by relative vigor in subsequent growth, but the treatments with the cold miscible paraffins were injurious. The varieties

Ophelia, Los Angeles and Luxemburg were used in these experiments. There were differences in response between the varieties but in general all were affected the same way.

In a study of factors affecting overwintering of roses, Moore (1942) tried, among other treatments, the complete waxing of the bushes in autumn with Parawax. The leaves were all removed from the plants and then wax was hand-brushed on from a wax melter. Results, as measured by total growth and number of blooms produced the following season, indicated that the waxing was superior to any of the other procedures tried. Other treatments were (1) wintered outside, (2) wintered in cellar, (3) wintered in trench, and (4) wintered in pit. The data indicated that waxing was so superior that the author concluded:

> Waxing rose plants for winter protection has given promising results from the standpoint of protection from winter-killing. With this fact established, the next step is to find a cheaper and less laborious method of applying the wax for the treatment to be practicable.
>
> The work with waxed and unwaxed rose canes indicates the killing may be attributed to a process of drying to death. Since the experiments were planned on the assumption that killing was due to freezing to death, further research based on this theory of killing due to drying, should be fruitful of some practical protective measure.

No information was given on the storage treatment of the waxed roses. If they were dug in the fall and replanted in the spring, it is possible that the beneficial effect of the waxing may have been due in part to the prevention of desiccation after replanting.

In 1951, Foret reported on a field test of waxed and unwaxed roses to determine if the waxing had any effect on growth. Four varieties, Mme. Jules Bouche, Joanna Hill, Picture, and President Hoover were used. Eighty plants of each variety were obtained, 40 waxed and 40 unwaxed. All plants were pruned to four inches, planted in the field and covered completely with soil.

As measured by number of days to sprouting there were no important differences between the varieties nor between the two treatments in any variety. In number of sprouts per plant and days to first bloom there were appreciable differences between varieties, but no significant differences due to treatment.

Although the test did not show any detrimental effect due to waxing; neither did it show any beneficial effects. This can probably be ascribed to the fact that the canes were completely covered with soil, and both waxed and unwaxed plants were exposed to the same moist environment.

Johnson and Janne in 1954 reported on some experiments to determine if the waxing of rose bushes is beneficial. Two locations were used, Weslaco and Spur, both in Texas. Five varieties of ten plants each were used in each location. Each variety of ten plants was divided into two groups of five each, waxed and unwaxed.

Data for the results at Weslaco were not given, but the authors report: "The unwaxed plants started growth later than the waxed ones and the growth was not as good during the spring."

For the planting at Spur, data given were (1) average number of days to first leaf, (2) average number of days to full leaf, (3) average number of days to first bud, (4) average number of days to first bloom, (5) average number of buds and blooms on May 26, and (6) vigor rating. In every variety, the waxed plants leafed out earlier and bloomed earlier. With the exception of one variety, the waxed plants had more buds and blooms on May 26, and the same was true of vigor. The authors concluded:

> The results showed the waxed plants to be superior at both locations. The waxed plants started growth sooner, bloomed earlier and more profusely and were more vigorous.

In 1955, Lyle reported on a study of maximum waxing temperatures for roses. He used a group of No. 1 grade bushes of Talisman variety. The wax used was National Wax Co. 204-H, a clear or light cream type which is in general use. Treatments were a combination of six temperatures and three lengths of time in dipping. Temperatures were at 170, 180, 190, 200, and 208°F, and times of dipping were one, three, and six seconds. The packaged bushes were dipped so as to cover the bud union and the top of the wrap. The waxed plants were stored at 34°F for 14 days; then kept in the laboratory at room temperature for ten days to simulate timing and handling in getting to a customer, following which they were planted on February 26, 1954 in 3-gallon containers. Results were:

> Up to June 1 no notable differences could be detected either in size of bush, number of canes, number of flowers, time of blooming, or quality of bloom. By September 1, only one plant was lost and it may not have been due to the wax; it happened to be the one subjected to the waxing at 208°F for six seconds. The plant treated at the same temperature but for 3 seconds dipping time appeared weak. For this reason it was thought that the waxing temperature was safe at least up to 200°F. The duration of 6 and also 3 seconds dipping time was considerably larger than normally used in commercial processing. Even 1 full second would be larger than used by most firms.

The number of plants used in the experiment was not given, but it appears that only one was used per treatment and there was no replication.

Methods of Applying Waxes

After it became apparent that the dipping of the tops of dormant woody plants in melted paraffin was beneficial, many sought to simplify the process. Dipping was impractical for many large plants because of the large wax container required, as well as the large amount of wax needed. Also, it was somewhat time consuming to melt the large quantities of wax required for dipping, and it was necessary to maintain the wax temperature within certain limits.

Maney (1931) described a device for spraying melted wax with the aid of compressed air. One great disadvantage of the procedure was the rapid congealing of the wax after it left the spray nozzle, resulting in very rough and uneven application. There is no evidence that the procedure found commercial acceptance.

Another possible method of applying wax is in dissolved form, in conjunction with a volatile solvent. This method has been tried in experiments on fruits (Magness and Diehl, 1924 and Bose and Basu, 1954) but apparently has not been tried on other plant materials. The method does not hold great promise because wax solvents tend to be toxic to plant tissue, and most are highly flammable.

The application of wax in emulsified form has been developed to a high degree in recent years, particularly for fruits and vegetables. Some of the reasons for this are the relative ease of application and the fact that a thinner coat of wax can be applied which interferes less with the relatively high rates of respiration of soft plant materials. Also, a thin layer of wax does not detract from the appearance of the fruit or vegetable. A thorough review of the development of wax emulsions and their use is contained in a paper by Miller, et al. (1950).

For nursery stock, roses in particular, the most practical method at present for applying paraffin wax still seems to be by dipping in the melted wax. On a commercial scale, the equipment needed for melting the wax is relatively simple and inexpensive. With modern thermostats, temperature control is no problem.

FIELD EXPERIMENT

Purpose

Since there is little data in the literature to conclusively prove or demonstrate the effects of dipping roses in melted paraffin it seemed most desirable to begin with an experiment in which the plants would be handled in a manner similar to that by nurserymen, and to subject the plants to the same conditions as in the average garden. In this way it would be possible to evaluate the overall effects of the waxes under conditions of actual practice.

Materials and Method

As the main purpose was to compare the effects of waxing with no waxing, these were the principal treatments used. The waxes commercially available, however, are of two kinds, the natural cream colored wax and the same wax tinted green by the addition of a dye. Since it is possible the green coloring may have effects of its own or may modify the effects of the uncolored wax, the green wax was used as an additional treatment, making a total of three.

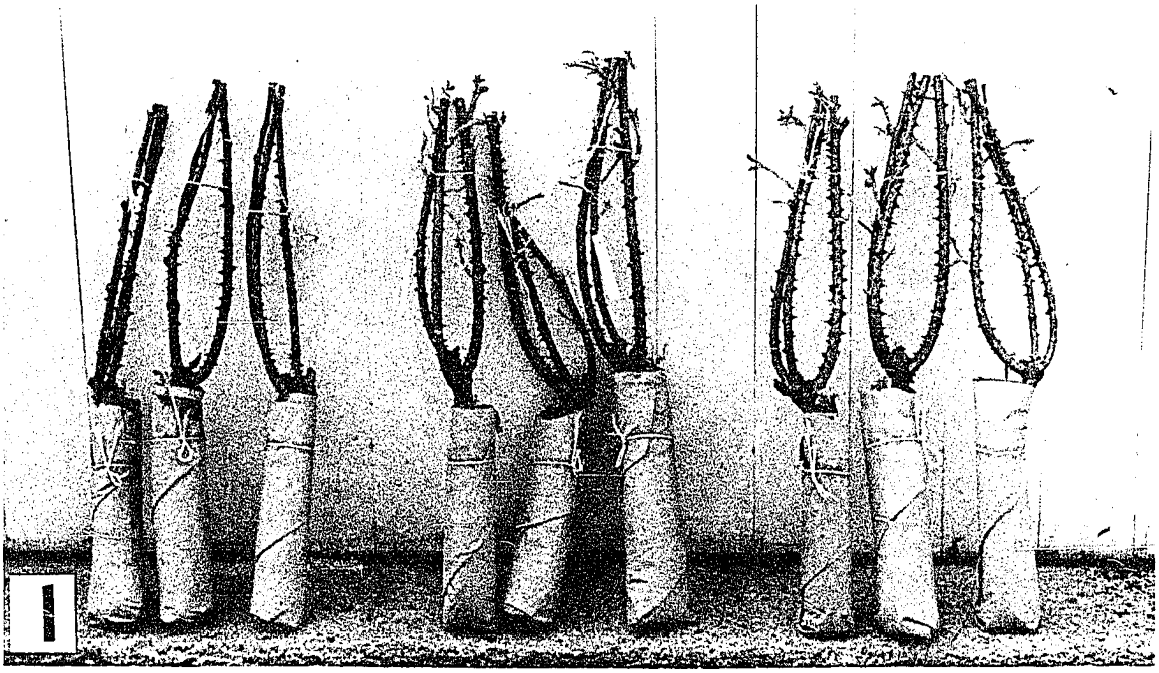
Since some nurserymen were of the opinion that hot weather has an adverse effect on waxed roses, it was decided to divide the experiment into three separate planting dates, on the assumption that temperatures would be higher at the later dates. This also had the advantage of not having to expose all of the experimental material to the hazards of weather at one time.

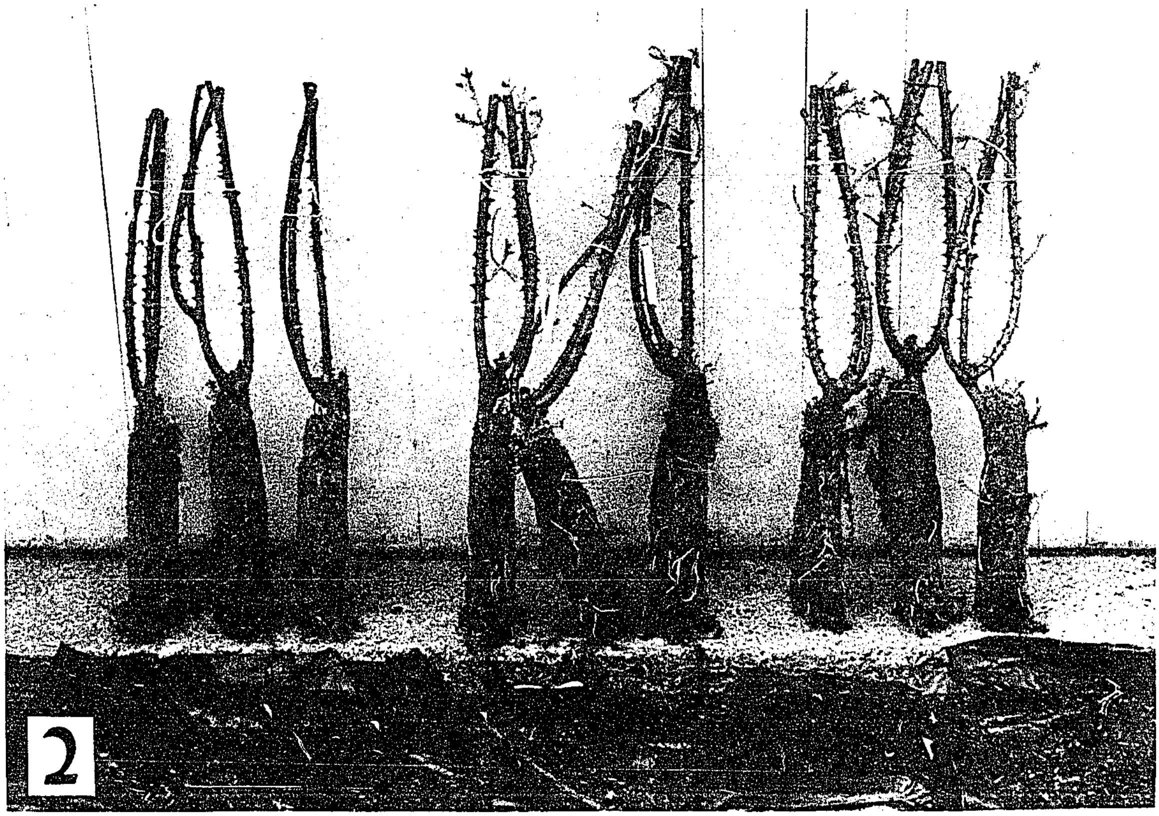
Three hundred grade number one rose bushes of the variety Crimson Glory were received at Ames on March 21, 1957 from a commercial nursery in Shenandoah, Iowa. As customary with the trade, they were tied in bundles of ten plants each. On receipt, the bundles were opened, 270 of the most uniform plants sorted out for the experiment, thoroughly mixed and then divided into three lots of 90 plants each. All bushes were placed in common storage at a temperature of about 35°F and a relative humidity near 100 per cent.

On April 3rd, 1957, the first of the three lots of 90 plants were individually pruned, both tops and roots, and root-wrapped with sphagnum moss and a sheet of asphalt coated paper. The tops were pruned to a length of 16 inches above the bud union and the number of canes remaining varied from two to four, depending on their size. Most plants had three canes, a few had four, and only a very few were left with two canes. The roots were pruned to a length of about ten inches below the bud union. Sufficient moist sphagnum moss was wrapped around the roots to make a root wrap of approximately three inches in diameter and twelve inches long. Figures 1 and 2 show the wrapped plants and the wrapping materials.

Figure 1. Wrapped plants showing shoot growth. Plants ready for the second planting. Photographed May 27, 1957. Left to right, in groups of three: untreated, green waxed, and cream waxed. Note the shoot growth on the waxed plants compared to the absence of shoot growth on the untreated

Figure 2. Unwrapped plants showing root growth. The same plants as in Figure 1, arranged the same way, with the moistureproof paper removed. Note the fine new white roots on the surface of the sphagnum moss root ball of the waxed plants compared to the absence of new roots on the untreated





Five days after pruning and root wrapping, the first group of 90 plants was waxed. The 90 plants were first thoroughly mixed, then divided into three groups of 30 plants each for treatment. One group was waxed with cream wax, the second with green wax, and the third was left unwaxed. The waxing operation was accomplished by inverting the plant, dipping it in a tank of melted wax and withdrawing it as quickly as possible. The estimated time that the plant was in the wax was about two seconds for the distal ends of the canes, which were the first to enter the wax and the last to leave. The waxing tank was a double boiler type, electrically heated, and thermostatically controlled. Waxing temperatures ranged from 86.5 to 88.5°C (187.7 to 191.3°F). The waxes used were standard stock waxes called "cream rosebush wax" and "light green rosebush wax" from the National Wax Company of Chicago, Illinois.

The waxing was done in the basement of the horticulture building and it was necessary to move the plants from the horticulture farm for this purpose. In order to treat all lots the same except for the waxing, the untreated plants were also moved between the horticulture farm and the horticulture building.

After waxing, the green waxed plants were each marked with a wired wooden label to help distinguish them from those coated with cream wax in the event the waxes became coated with dust or otherwise became difficult to identify. Then the plants of all three treatments were thoroughly mixed, in order to avoid possible differences in subsequent storage, and moved back to the underground storage room at the horticulture farm.

Two weeks after waxing, all plants were moved from the cool underground storage to the relative warmth of an above ground frame utility shed. The purpose of this was to simulate conditions of shipping and perhaps display on a store counter.

One week after moving the plants into the warm shed, they were planted in the field according to a planned experimental design. In planting, a hole approximately 12 inches in diameter and 12 inches deep was dug for each plant; the root wrapping, including all of the sphagnum moss, removed; the plant placed in the hole with roots spread out as much as possible, and then the soil was returned. Since it was desired to give the wax treatments the maximum opportunity to show differences, the plants were not hilled up with soil following planting as is usually practiced with roses. Likewise, the canes were not pruned back but left at their full length of sixteen inches. Following planting, the plants were watered thoroughly with a garden hose.

The second planting was made four weeks after the first and the third planting four weeks after the second. All operations associated with each planting were similarly spaced. The first planting was made on April 29, the second on May 27, and the third on June 24.

The experimental plot was given normal cultural care through the summer. No important diseases or insect infestations were observed, and therefore no spraying or dusting was necessary.

Experimental Design

The field test was laid out as a two-factor factorial randomized complete block design. One factor was the wax treatments and the other factor the planting dates.

Six blocks (replicates) were used, each having all the nine treatment combinations of three waxes and three planting dates. The treatment combinations were independently randomized within each block.

For convenience in cultivation and to make most efficient use of available land, the six blocks were arranged in a straight line. Each block consisted of three rows, each containing three treatment combinations. Besides ease of cultivation the blocks were also arranged to parallel an overhead irrigation line in the event irrigation might be necessary. Rainfall, however, was adequate and evenly distributed throughout the summer and irrigation was unnecessary.

Each treatment consisted of five plants. Since there were nine treatment combinations and six replications, the total number of plants used was two hundred seventy.

Originally, three hundred plants were received for the experiment. Since this was only about ten per cent more than the required number it was impractical to select plants for uniformity. Instead, thirty of the most extreme sizes and shapes were rejected in order to keep the experimental lot as uniform as possible.

No efforts were made to select for uniformity of plants within blocks. This was impractical because of the different planting dates within each block. Instead, reliance was placed on random selection of plants for planting date, treatment, and replicate.

Statistical treatment of data was by analysis of variance. The sums of squares for planting dates were subdivided into linear and quadratic components. This was facilitated by the fact that intervals between successive plantings were equal. The sums of squares for waxes were subdivided into a set of two orthogonal comparisons for a more precise comparison of differences between the waxed treatments and the untreated, and of differences between the two waxes.

Results

Flower production

Since the primary purpose for planting roses is the production of flowers, the flowers produced throughout the season were counted and recorded. With a few exceptions counts were made every third day throughout the summer and fall. The technique was to cut off each flower, after the petals began to fall, recording the number at this time. In this manner, all flowers were allowed to come to full development and by cutting off the flower, the possibility of counting the same flower twice was avoided. The first flowers were counted on June 20 and the last on October 21.

The distribution of flower production through the season is shown in the curves in Figure 3, which also show the relative effects of the various treatments.

Several features of interest may be observed from the curves. Of greatest significance is that the unwaxed plants produced noticeably fewer flowers. Also, the first peak in blooming appears to be delayed in the unwaxed treatment. This is no doubt due to the slower re-establishment of the non-waxed plants. Also quite obvious is the fact that the curves for the two kinds of wax follow each other quite closely, indicating very little difference, if any, between them.

At the end of the season, all flowers were totaled for

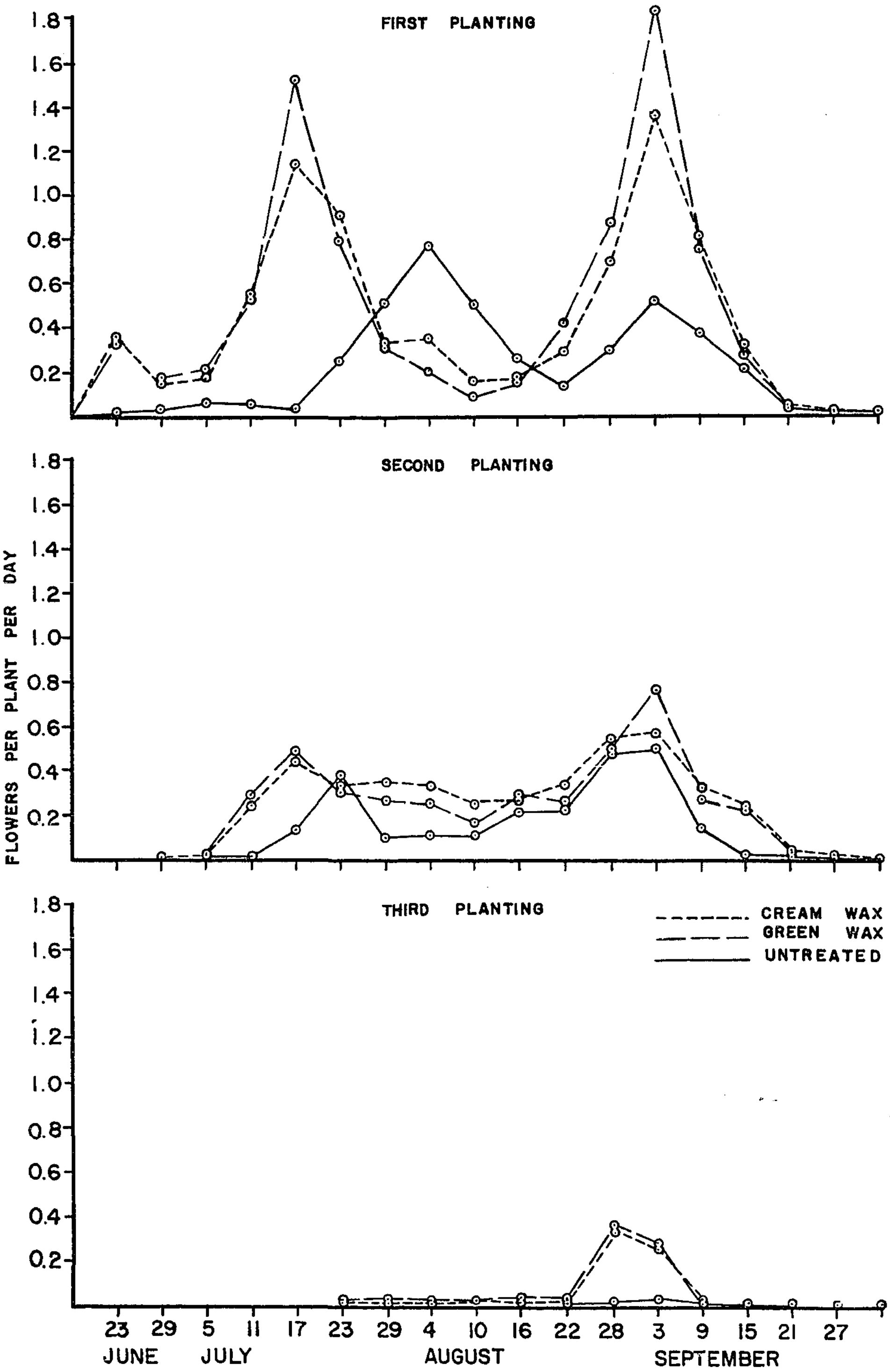


FIGURE 3. FLOWER PRODUCTION, SUMMER 1957

each of the individual treatments and analyzed statistically as shown in Table 1. An inspection of the treatment means will show that on the whole the waxed plants produced about 65 per cent more flowers than the untreated plants. Also, flower production was drastically reduced in the later plantings.

The analysis of variance shows that differences in both planting dates and wax treatments were significant at the one per cent level. A subdivision of the sum of squares for dates shows that the differences are linear, indicating a straight line relationship among the planting dates. In this case, flower production decreased as the date of planting was delayed. This does not mean, however, that the wax had a detrimental effect on later plantings, for the treatment means still show the same relationship between the waxed and non-waxed treatments as for the earlier planting dates.

Since the treatment means for the two waxes were quite close together, it was interesting to compare the effects of both waxes with the untreated, and to compare the two waxes with each other. By appropriately subdividing the sum of squares for treatment it can be seen that the comparison of both waxes with the untreated was highly significant, but the two waxes with each other were not. This indicates that nearly all of the differences were due to the two waxes versus the untreated, and for practical purposes the two waxes were

Table 1. Total flowers per plant, summer 1957

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
I	46.0	55.8	28.4	27.2	33.2	18.6	7.8	5.2	6.4	228.6
II	53.2	64.2	37.6	29.0	24.4	13.2	9.6	9.0	4.8	245.0
III	42.4	53.0	27.2	30.6	19.6	14.6	9.8	8.6	4.2	210.0
IV	42.6	46.6	24.0	26.0	26.4	17.4	10.8	7.2	6.6	207.6
V	52.8	45.6	32.2	24.2	28.0	15.6	7.8	8.8	5.2	220.2
VI	48.6	41.4	31.4	22.2	25.2	17.8	8.4	8.4	7.6	211.0
Treatment sums	285.6	306.6	180.8	159.2	156.8	97.2	54.2	47.2	34.8	1322.4
Treatment means	47.6	51.1	30.1	26.5	26.1	16.2	9.0	7.9	5.8	

Date and wax sums

April 29 planting	773.0	Cream waxed	499.0
May 27 planting	413.2	Green waxed	510.6
June 24 planting	136.2	Untreated	312.8

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	5	114.76	22.9520	1.418
Treatments	8	13285.03	1660.63	102.6**
Dates	2	11327.11	5663.51	349.9**
Linear	1	11264.28	11264.28	695.9**
Quadratic	1	63.48	63.48	3.922
Waxes	2	1369.07	684.535	42.29**
C + G vs. U	1	1365.34	1365.34	84.35**
C vs. G	1	3.73	3.73	0.230
D x W	4	588.85	147.2125	9.095**
Error	40	647.47	16.18675	
Total	53	14047.26		

**Significant at the 1% level.

identical in effect.

The analysis of variance also shows there is some interaction between dates and waxes. This indicates that variations within one factor are not quite independent of the other factor. An inspection of the treatment means indicates that this interaction is no doubt due to the fact that in the third planting the percentage difference between the waxed plants and the untreated was less than for the first two plantings. The reason for this is that the weather following the third planting was more humid and the unwaxed plants were not retarded as much.

One observation with regard to flowering which the data do not show is that the treatments which produced the greatest numbers of flowers also produced the largest flowers. While size of the flowers is of considerable importance to the gardener it did not seem practical to take data on this effect because it would have been necessary to measure each individual flower, and at some particular stage of development.

Cane length survival

Shortly after the first planting was made it was obvious that a greater proportion of the unwaxed canes were dying back. This seemed a reasonable response on the assumption that the unwaxed canes were drying out faster and the poorly established root system was not yet able to replenish the moisture.

At the end of the growing season, after much of the foliage had fallen, the total original cane length as planted was measured. At the same time the total length of original cane that died back since planting was also recorded. It was not difficult to distinguish between dead and live cane, and the dead wood was more than firm enough to remain on the plant throughout the season.

By appropriate calculations, the data were converted to show percentage of original cane length surviving. The plants thus having the most live cane also have a corresponding higher per cent figure. A statistical analysis of the data is given in Table 2. The analysis of variance yields results similar to those for flowering. Namely, that differences within both dates and waxes are highly significant and there is practically no difference between the two waxes. There is also an interaction between dates and waxes, indicating that variations within one factor are not quite independent of the other factor.

Compared with flowering, there are smaller differences within dates and greater differences within waxes - with practically all of the difference between the two waxed treatments and the unwaxed.

One reason for the smaller differences within dates can be seen in the treatment mean for the non-waxed plants of the

Table 2. Per cent of original cane length surviving

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
I	85.2	88.3	33.1	84.4	80.8	29.4	70.5	61.1	61.9	594.7
II	79.2	93.7	43.0	73.4	75.5	21.7	58.5	74.3	39.3	558.6
III	86.2	92.3	30.4	79.1	61.6	23.7	64.6	75.4	34.6	547.9
IV	89.4	84.6	29.9	77.3	80.4	26.3	68.3	59.4	51.4	567.0
V	78.7	90.6	30.9	74.6	73.7	23.7	47.0	70.3	35.5	525.0
VI	85.7	75.0	26.9	72.0	75.4	38.3	69.2	50.0	52.5	545.0
Treatment sums	504.4	524.5	194.2	460.8	447.4	163.1	378.1	390.5	275.2	3338.2
Treatment means	84.1	87.4	32.4	76.8	74.6	27.2	63.0	65.1	45.9	

Date and wax sums

April 29 planting	1223.1	Cream waxed	1343.3
May 27 planting	1071.3	Green waxed	1362.4
June 24 planting	1043.8	Untreated	632.5

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	5	308	62	1.13
Treatments	8	23224	2903	52.78**
Dates	2	1036	518	9.42**
Linear	1	893	893	16.24**
Quadratic	1	137	137	2.49
Waxes	2	19228	9614	174.8**
C + G vs. U	1	19218	19218	349.4**
C vs. G	1	10	10	0.18
D x W	4	2960	740	13.45**
Error	40	2207	55	
Total	53	25739		

**Significant at the 1% level.

last planting. This value is actually higher than the untreated for the second planting date. The reason for this is that the weather the few days following the third planting was rainy, humid and relatively cool. Also there was less wind movement, which further reduced the transpirational stresses on the non-waxed plants. Table 3 gives the weather data as taken from official weather records[1]. The weather station is located on the Iowa State College agronomy farm, less than one mile from the experimental plot. The data in the table are for the first five days following each planting, which seems to be the most critical period after planting. A separate experiment, to be reported later in this paper shows that non-waxed rose canes may lose most of their water the first four days.

Data for rainfall show that it rained a little every day for four days after the third planting. Although there was more total rainfall the five days after the second planting, apparently it fell rapidly in short periods of time or at night because evaporation on the same days was about as high as for non-rainy weather. The wind data also show there was less evaporational stress after the third planting because there was less than two thirds as much wind movement as there was following each of the first two plantings. Temperatures

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[1]United States Weather Bureau. 1957. Climatological data, Iowa section. 68: 53-93.

Table 3. Weather data for five days after each planting

Planting date	Day after planting 1st	2nd	3rd	4th	5th	Total	Average
			Rainfall in inches				
April 29 planting	0	0	0	T	0	Trace	Trace
May 27 planting	0	.02	1.23	.01	0	1.26	0.25
June 24 planting	.34	.03	.09	.08	0	0.54	0.11
			Evaporation in inches				
April 29 planting	.25	.24	.27	.34	.25	1.35	.270
May 27 planting	.27	.24	.25	.10	.33	1.19	.238
June 24 planting	.13	.18	.10	.21	.24	.86	.172
			Wind in miles per day				
April 29 planting	36	31	72	126	77	342	68.4
May 27 planting	83	81	55	20	99	338	67.6
June 24 planting	66	38	34	47	33	218	43.6
			Temperatures in °F				
April 29 planting							
Maximum	78	80	75	67	61	361	72.2
Minimum	46	49	55	46	32	228	45.6
May 27 planting							
Maximum	78	82	76	78	75	389	77.8
Minimum	46	55	61	57	55	274	54.8
June 24 planting							
Maximum	77	75	68	79	85	384	76.8
Minimum	52	59	53	57	61	282	56.4

also tended to favor the third planting. The average maxima and minima for the five days following the third planting were about the same as for the second planting, when they should normally have been higher. Temperatures no doubt were depressed because of the cloudy rainy weather.

Top growth

As an indicator of the effect of the paraffin waxes on the general overall growth of the rose plants, two measurements of the tops were taken; one was the number of new shoots arising from the original canes and bud union, and the other was the total length of growth in inches.

The two measurements were made at the same time, in late fall after most of the leaves had fallen. The length of each shoot was recorded separately, and the number of measurements represented the actual number of shoots.

Table 4 gives the average number of new shoots per plant for the various treatments and an analysis of variance. It is noted that the waxed plants, for the first two plantings produced about twice as many new shoots as the unwaxed. The same relationship does not quite hold for the third planting, where the number of new shoots produced by the unwaxed plants is only slightly less than the waxed. The reason for this is undoubtedly related to the fact that a larger proportion of the canes survived and hence more buds were available to produce the new shoots.

Differences between treatments for numbers of new shoots are about the same as for flowers; namely that there is a highly significant difference between dates of planting and between waxed and non-waxed plants.

Table 5 gives the data and statistical analysis for total

Table 4. Number of new shoots per plant

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
I	21.0	22.6	11.2	20.0	19.0	9.4	15.2	11.0	13.0	142.4
II	22.4	26.6	12.8	15.8	17.4	7.6	11.6	12.6	9.6	136.4
III	21.4	22.4	10.6	18.8	17.2	9.4	15.0	13.6	8.4	136.8
IV	21.2	22.0	9.2	20.2	19.6	7.4	14.8	13.4	11.2	139.0
V	17.8	25.0	10.8	17.0	17.4	8.6	12.6	14.2	8.6	132.0
VI	20.2	20.0	11.8	15.8	15.6	8.6	10.6	10.2	10.4	123.2
Treatment sums	124.0	138.6	66.4	107.6	106.2	51.0	79.8	75.0	61.2	809.8
Treatment means	20.67	23.10	11.07	17.93	17.70	8.50	13.30	12.50	10.20	

Date and wax sums

April 29 planting	329.0	Cream waxed	311.4
May 27 planting	264.8	Green waxed	319.8
June 24 planting	216.0	Untreated	178.6

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	5	24.89	4.9780	1.9315
Treatments	8	1221.10	152.263	59.08**
Dates	2	356.89	178.4450	69.24**
Linear	1	354.694	354.694	137.6**
Quadratic	1	2.19592	2.19592	0.852
Waxes	2	697.10	348.550	135.2**
C + G vs. U	1	688.14	688.14	267.0**
C vs. G	1	8.97	8.97	3.480
D x W	4	167.11	41.77750	16.21**
Error	40	103.09	2.57725	
Total	53	1349.08		

**Significant at the 1% level.

Table 5. Total shoot growth per plant in inches

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
I	212.4	231.0	139.4	150.8	159.6	96.6	93.4	63.2	58.4	1204.8
II	227.0	270.2	136.4	117.0	135.4	63.8	73.4	61.2	51.8	1136.2
III	212.0	219.2	100.6	154.4	118.4	94.2	97.6	66.0	37.0	1099.4
IV	182.4	211.4	97.8	127.6	148.4	80.0	73.0	84.4	51.8	1056.8
V	185.6	206.8	98.4	127.2	128.0	62.8	68.0	83.8	45.0	1005.6
VI	205.2	195.2	110.8	102.4	106.6	67.2	65.4	55.6	59.8	968.2
Treatment sums	1224.6	1333.8	683.4	779.4	796.4	464.6	470.8	414.2	303.8	6471.0
Treatment means	204.1	222.3	113.9	129.9	132.7	77.4	78.5	69.0	50.6	

Date and wax sums

April 29 planting	3241.8	Cream waxed	2474.8
May 27 planting	2040.4	Green waxed	2544.4
June 24 planting	1188.8	Untreated	1451.8

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	5	4185.46	837.09	3.471*
Treatments	8	172688.89	21586.11	89.51**
Date	2	118210.99	59105.49	245.1**
Linear	1	117078.03	117078.03	485.5**
Quadratic	1	1132.963	1132.963	4.698*
Waxes	2	41576.8	20788.40	86.20**
C + G vs. U	1	41442.25	41442.25	171.8**
C vs. G	1	134.56	134.56	0.558
D x W	4	12901.10	3225.27	13.37**
Error	40	9646.35	241.15875	
Total	53	186520.70		

*Significant at the 5% level.

**Significant at the 1% level.

growth of new shoots in inches. In general, the differences are about the same as for number of new shoots, with two minor exceptions. The differences between blocks is significant at the five per cent level as is also the quadratic component of variance within dates. These, however, do not detract appreciably from the large differences within dates and within waxes, and probably only reflect the difficulty of making accurate measurements of length, owing to the curvature of some canes and the difficulty sometimes of deciding exactly where a leafy shoot ends.

Root growth

In the spring of 1958, the year following the planting of the experimental material, four out of the six replicates were dug in order to study the root systems. Blocks III, IV, V, and VI were removed from the field, but Blocks I and II were allowed to remain in order to determine if there would be any overwintering effects attributable to the applied treatments. The plants were undercut at a depth of about 12 inches by means of a U-shaped steel bar mounted on the rear of a tractor. They were then bundled according to treatment, labeled, and moved to an underground common storage.

The tops of the plants were cut off just below the bud union and discarded, after data relative to the amount of original viable cane which survived the winter were recorded.

The roots were each shaken thoroughly to remove any soil particles and then weighed on a gram scale. Since it was apparent that the waxed plants had more new roots than the non-waxed, all new roots of one-sixteenth inch diameter or larger were counted and recorded.

Table 6 presents the data as well as the analysis of variance for root weight. In general the differences within planting dates and within waxes agree with the other measurements taken, particularly flowering and length of new growth.

Table 7 records the number of new roots per plant. Results here agree well with root weight, but the variation within dates does not quite follow a straight line as indicated by a small significant quadratic component of variance. Also some interaction between dates and waxes shows up. Both these variations appeared, most probably, because of variation in the loss of new roots in digging and handling, and the difficulty of counting.

In spite of the fact that only four replicates were used to obtain the data, the differences were very significant. In fact, root weight appears to have given nearly ideal results, all measurements considered. The response for dates is practically entirely linear, variance within waxes almost entirely due to the two waxes versus the non-waxed, and no significant interaction, indicating the same amount of difference within waxes for each planting date.

Table 6. Root weight per plant in grams

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
III	125	122	93	95	91	78	85	68	65	822
IV	115	118	81	103	113	85	86	77	69	847
V	117	121	97	108	90	90	84	89	71	867
VI	114	114	106	84	97	82	72	76	65	810
Treatment sums	471	475	377	390	391	335	327	310	270	3346
Treatment means	117.75	118.75	94.25	97.50	97.75	83.75	81.75	77.50	67.50	

Date and wax sums

April 29 planting	1323	Cream waxed	1188
May 27 planting	1116	Green waxed	1176
June 24 planting	907	Untreated	982

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	3	217.00	72.3333	1.291
Treatments	8	9690.39	1211.29875	21.62**
Dates	2	7210.72	3605.36	64.36**
Linear	1	7210.66	7210.66	128.7**
Quadratic	1	0.05555	0.0555	0.001
Waxes	2	2228.22	1114.11	19.89**
C + G vs. U	1	2222.22	2222.22	39.67**
C vs. G	1	6.000	6.000	0.107
D x W	4	251.45	62.8625	1.122
Error	24	1344.50	56.02083	
Total	35	11251.89		

**Significant at the 1% level.

Table 7. Number of new roots per plant

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
III	32	37	18	24	20	16	18	17	14	196
IV	32	34	17	24	23	18	18	16	12	194
V	38	40	21	21	24	20	14	18	11	207
VI	38	28	23	18	18	15	18	19	16	193
Treatment sums	140	139	79	87	85	69	68	70	53	790
Treatment means	35.00	34.75	19.75	21.75	21.25	17.25	17.00	17.50	13.25	

Date and wax sums

April 29 planting	358	Cream waxed	295
May 27 planting	241	Green waxed	294
June 24 planting	191	Untreated	201

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	3	13.89	4.63	0.511
Treatments	8	1926.39	240.79875	26.56**
Dates	2	1224.39	612.1950	67.52**
Linear	1	1162.04	1162.04	128.2**
Quadratic	1	62.3472	62.3472	6.876*
Waxes	2	485.72	242.860	26.78**
C + G vs. U	1	485.68	485.68	53.57**
C vs. G	1	0.04	0.04	0.004
D x W	4	216.28	54.070	5.963**
Error	24	217.61	9.06708	
Total	35	2157.89		

*Significant at the 5% level.

**Significant at the 1% level.

Plant survival over winter

At the time four of the replicates were dug for study of the roots, it was observed that the waxed plants appeared to have more live budwood.

At the conclusion of measurements the preceding fall, there were no plans to carry the experimental planting through a second season since it was assumed that most of the effects of the waxing would be confined to the relatively short time following replanting. Therefore the plants were not hilled up with soil before freezing weather as is sometimes done to protect the canes from severe kill back. Snowfall through the winter was rather light but, fortunately, there was some snow cover during the periods of lowest temperatures. The lowest temperature recorded was 24°F below zero. This was low enough to kill all canes back to the level of the snow cover, which was about three inches.

Because the winter killing had the effect of pruning all tops to the same height of three inches, it was impractical to attempt rating survival by the amount of tops remaining. Therefore a record was kept simply on whether a plant had any live cane remaining, as it appeared that the tops of most of the weaker plants died off completely.

All six replicates in the experiment were used in obtaining the data for cane survival. The four replicates that were removed from the field were counted at the time of root examination, and the two remaining replicates were counted in the field after spring growth had begun.

The data are presented in Table 8. Treatment means refer to the average number of plants with live cane remaining, from the original five plant groups. The data show the highest survival for plants in the first planting date as might be expected. One interesting thing about the waxed versus the unwaxed plants is that the differences were rather small for the first planting and became greater as planting was delayed. This probably indicates that only plants above a certain threshold of size and maturity were capable of surviving the winter. In the case of the first planting, even the non-waxed plants were large enough by the end of the season to survive the winter. But the plants in the last two plantings were so delayed in development that only those aided by the waxing had become strong enough to overwinter successfully.

The analysis of variance shows that there is a significant difference between blocks. This is not of particular importance and probably only indicates that there may have been differences in snow cover from block to block. Differences within planting dates and within waxes follow the same trends as with other measurements and confirm the beneficial effects of waxing.

Table 8. Number of plants per treatment surviving over winter

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
I	4	5	4	5	5	4	2	2	2	33
II	4	5	4	3	2	2	4	1	0	25
III	4	5	4	3	5	4	2	5	2	34
IV	4	5	3	5	5	2	4	1	2	31
V	5	5	5	4	4	3	3	3	1	33
VI	5	5	5	5	5	5	3	4	3	40
Treatment sums	26	30	25	25	26	20	18	16	10	196
Treatment means	4.33	5.00	4.17	4.17	4.33	3.33	3.00	2.67	1.67	

Date and wax sums

April 29 planting	81	Cream waxed	69
May 27 planting	71	Green waxed	72
June 24 planting	44	Untreated	55

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	5	17.03704	3.40740	4.652**
Treatments	8	52.25926	6.53240	8.919**
Dates	2	40.70371	20.35185	27.79**
Linear	1	38.02777	38.02777	51.92**
Quadratic	1	2.67592	2.67592	3.654
Waxes	2	9.14815	4.57407	6.245**
C + G vs. U	1	8.89815	8.89815	12.15**
C vs. G	1	0.2500	0.2500	0.341
D x W	4	2.40740	0.60185	0.822
Error	40	29.29630	0.73240	
Total	53	98.59260		

**Significant at the 1% level.

Flower production, second spring

Although only two out of the original six replicates remained in the field the year after the original planting, the differences between waxed and non-waxed plants were still obvious.

Figure 4 shows in graphic form the distribution of flower production indicated as flowers per plant per day. In spite of the small number of plants remaining it is quite clear that the two waxes are similar to each other in effect, and the waxed plants are superior to the unwaxed.

Perhaps, in this case it is not quite correct to say that the effects here are due to the wax, because practically none of the original waxed cane remained. The best explanation is that the plants that were originally waxed grew more vigorously the first year, overwintered better and were therefore in better condition to start second year growth. This is shown by the data on root weight and number of new roots.

Table 9 gives the data and analysis of variance. Because of the small numbers of plants, differences do not show up as well as other measurements using more replicates. Nevertheless, the differences between waxed and non-waxed plants are significant at the five per cent level.

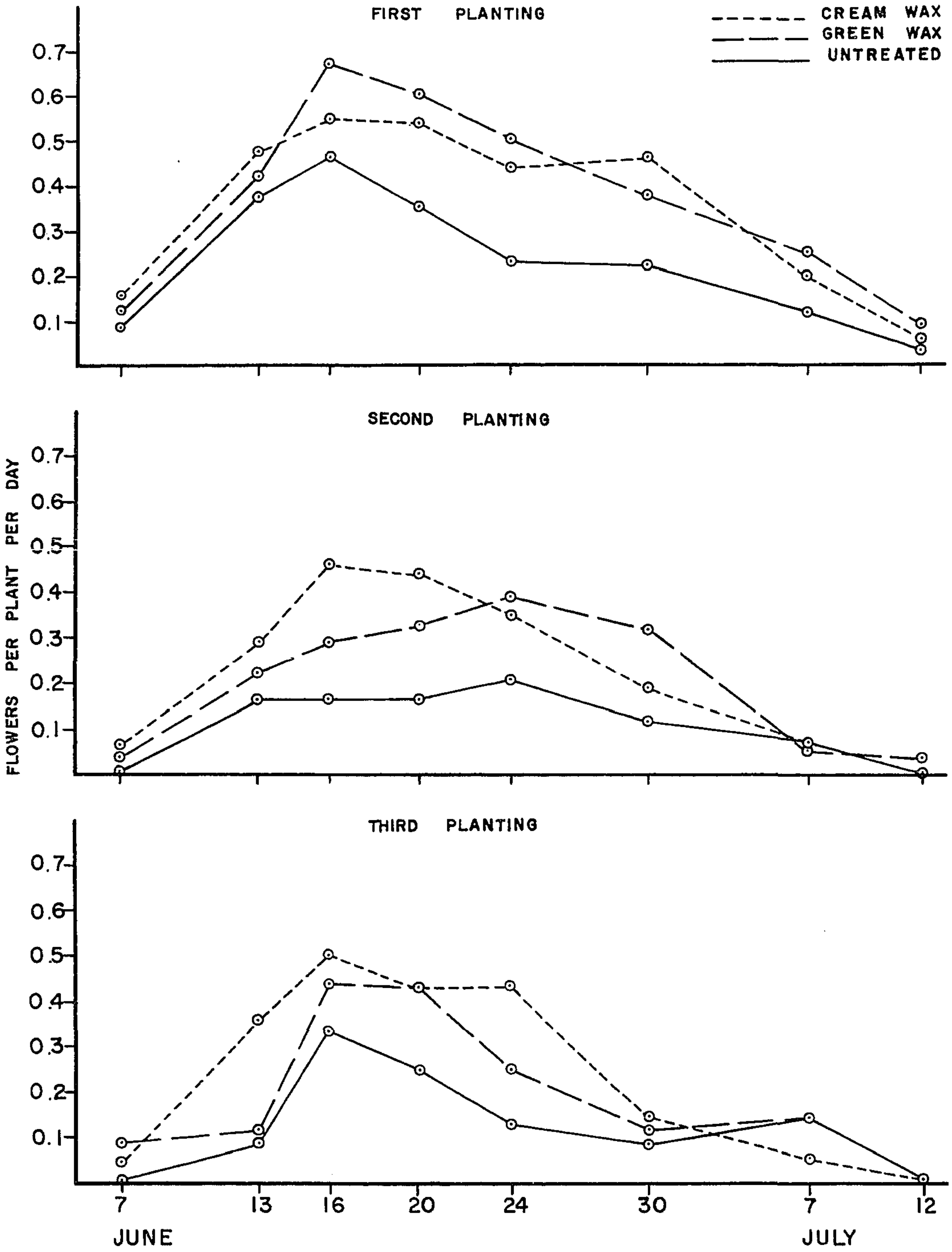

FIGURE 4. FLOWER PRODUCTION, SPRING 1958

Table 9. Total flowers per plant, spring 1958

Blocks	Treatments									Block sums
	April 29 planting			May 27 planting			June 24 planting			
	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	Cream waxed	Green waxed	Un-treated	
I	8.00	14.20	8.75	9.60	9.00	4.75	10.00	9.50	4.50	78.30
II	19.00	13.20	8.00	5.67	4.00	2.00	7.50	1.00	0.0	60.37
Treatment sums	27.00	27.40	16.75	15.27	13.00	6.75	17.50	10.50	4.50	138.67
Treatment means	13.50	13.70	8.38	7.63	7.50	3.38	8.75	5.25	2.25	

Date and wax sums

April 29 planting	71.15	Cream waxed	59.77
May 27 planting	35.02	Green waxed	50.90
June 24 planting	32.50	Untreated	28.00

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Blocks	1	17.86027	17.86027	1.223
Treatments	8	254.10568	31.76321	2.176
Dates	2	155.86388	77.93194	5.338*
Linear	1	124.48520	124.48520	8.526*
Quadratic	1	31.37866	31.37866	2.149
Waxes	2	89.57989	44.78994	3.068
C + G vs. U	1	83.02246	83.02246	5.686*
C vs. G	1	6.56241	6.56241	0.449
D x W	4	8.66191	2.16547	0.148
Error	8	116.79968	14.59996	
Total	17	388.76563		

*Significant at the 5% level.

Discussion

Individual statistical analyses of each of the eight measurements taken in the field experiment show beyond a reasonable doubt that the overall effects of the waxes were beneficial. In no case was there any evidence that the wax was detrimental in the least, either by direct scrutiny of flowers, leaves, and canes throughout the summer, or by the measurements taken.

To make the results easier to visualize, the treatment means for each measurement are presented in Figure 5 in the form of a histogram. The most consistent fact demonstrated is that response decreased with delayed planting. It can also be seen that regardless of planting date the response of the unwaxed plants was less than for the waxed. Of interest is the fact that the magnitude of differences between planting dates is not always the same. The differences in numbers of flowers produced are much greater than root weights, although the overall trend is the same.

One important fact is more obvious in Figure 5 than in the tables of mean values. This is that the response of the unwaxed of the last planting date is in some cases greater than the unwaxed for the second planting date. This can be seen in both per cent of original cane length surviving and in number of new shoots. This has already been explained as due to moist, cool weather following the last planting.

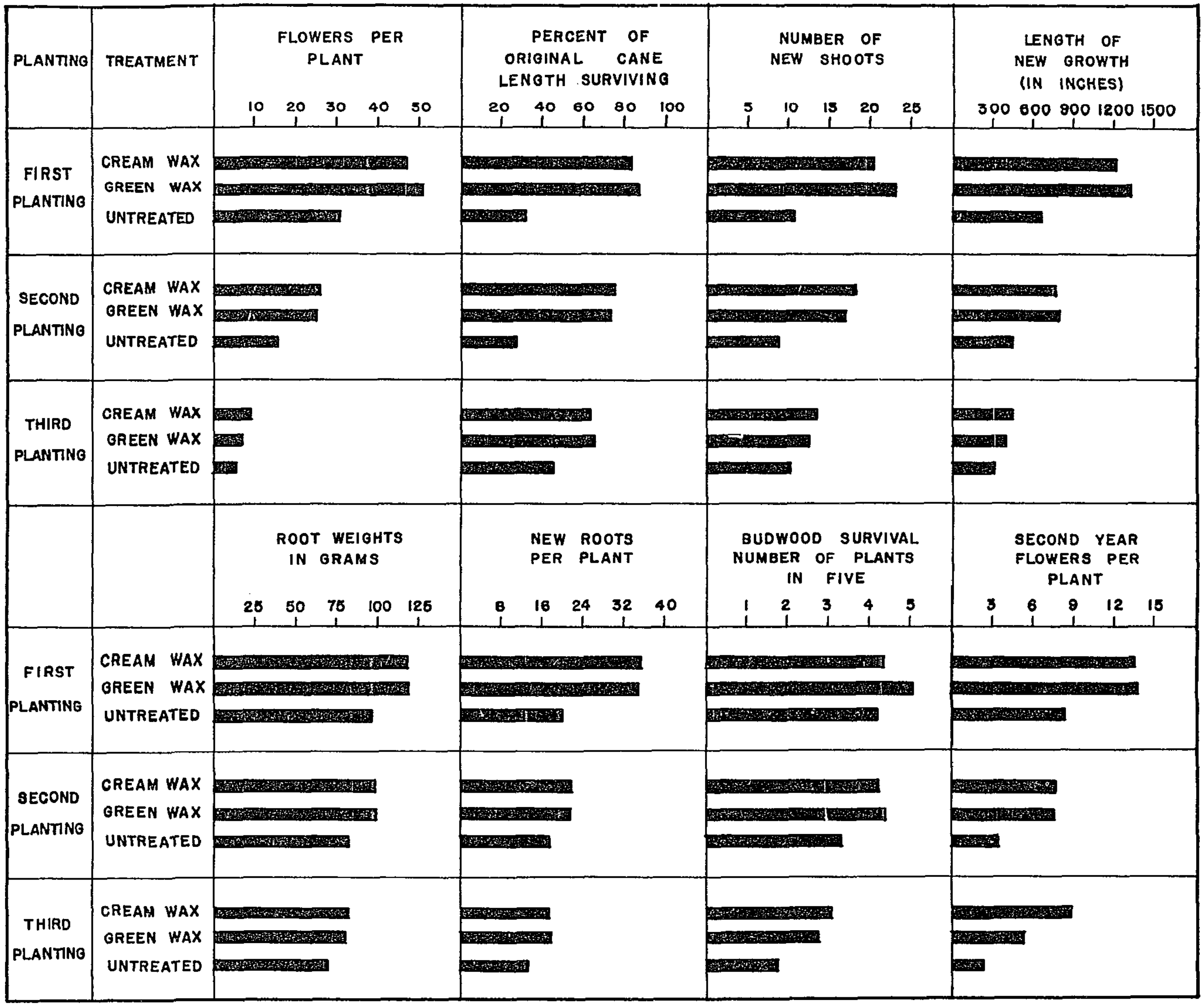

FIGURE 5. GRAPHIC SUMMARY OF FIELD EXPERIMENT

It is interesting to note that although the number of new shoots in the unwaxed plants for the last planting is greater than the corresponding treatment in the second planting, this trend is not followed by length of new growth. The number of new shoots depended on the per cent of original cane length surviving, which in turn depended on the weather for the few days after planting. The length of new growth, on the other hand, responded to conditions over the entire season. This points up the fact that in experiments of this type, the kinds of measurements taken must be chosen with care. In this case, both measurements were useful. The number of new shoots reflects the short term effect of the waxes, and the length of new growth, the long term effect.

It is noted that for many measurements, the differences between waxed and unwaxed plants in the last planting are less than the corresponding differences in the first two plantings. Although the rainy weather is assumed to be responsible for this development, of greater importance is the fact that under certain weather conditions the differences between waxed and unwaxed plants may not be apparent. It was fortunate that the experiment was divided into several plantings. If the entire experiment had been planted on a single date, the very important short term effect of the waxes may not have been revealed. If all treatments had been planted on the last planting date, or if the early plantings had been followed by unusual weather similar to that after the last planting, the magnitude of differences between waxed and unwaxed plants would have been considerably less.

Since the primary purpose of planting roses is the production of flowers, it was desirable that this be used as a criterion for measuring the effects of treatment. This particular measurement, however, is considerably more time consuming than for some of the other measurements taken. An inspection of the histograms shows that length of new growth seems to correlate quite well with the number of flowers, and might have been just as useful for evaluating the results of this particular experiment. Root measurements correlate well also, but the fact that the roots would have to be dug reduces the usefulness of these measurements, although they may be useful in cases where the tops may have been lost or utilized in some way. Although number of shoots produced by a plant is sometimes used in evaluating treatment, it did not appear to be the most valid criterion in this experiment.

CONTROLLED HUMIDITY STORAGE EXPERIMENT

Purpose

At the times of planting in the field experiment, it was observed that the waxed plants had produced more new shoots than the unwaxed. Also it was observed that more new roots had been initiated in the sphagnum moss root wrap by the waxed plants. Although these responses were obvious in the first planting, not until the second planting was it apparent that they were going to be consistent. Because of the necessity for completing each field planting in as short a time as possible, no data on root and shoot growth were taken. However, photographs were made of representative samples of the plants, and are reproduced as Figures 1 and 2.

At the time of planting, the unwaxed canes appeared to shrivel somewhat compared with the waxed. Moisture tests made on samples taken at this time might have yielded interesting results, but would have necessitated removal of some of the canes. Besides, some preliminary moisture tests made on other rose canes indicated that moisture percentages varied widely from cane to cane, even on the same plant, depending on size, contact with other materials, and exposure.

For these reasons another experiment in which both temperature and humidity would be controlled and the plants allowed to come to a definite equilibrium with the humidity was arranged to permit more accurate moisture determinations.

Materials and Method

Three moisture proof cabinets were arranged inside of a walk-in type refrigerator to serve as humidity controlled storage spaces. These cabinets were actually old household type refrigerators from which the cooling mechanisms had been removed. The inside dimensions of each cabinet were 30 inches high, 22 inches wide, and 16 inches deep. Humidities were controlled by pans of saturated salt solutions over which a small two inch diameter fan circulated the air. The relative humidities maintained were approximately 100, 75 and 50 per cent. For the 100 per cent relative humidity the pan contained only distilled water. For the 75 and 50 per cent relative humidities the salts used were sodium chloride ($NaCl$)[1] and sodium bisulphate ($NaHSO_4$)[2] respectively.

Each environment contained plants which were waxed, dipped in hot water, and untreated. The field experiment had shown that there was no significant difference between the two waxes tried, so only the "cream wax" was used here. Some

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[1] Wexler, Arnold and W. G. Brombacher. 1951. Methods of measuring humidity and testing hygrometers. National Bureau of Standards Circular 512. United States Department of Commerce, Washington, D.C.

[2] Handbook of chemistry and physics, 39th ed. [c1957] Chemical Rubber Publishing Company, Cleveland, Ohio.

preliminary trials of dipping rose canes in hot water at the same temperature as the wax, in an attempt to assess the effect of temperature alone, had shown that there was apparently some injury by the hot water.

Since each humidity cabinet would hold 30 plants, this allowed ten single-plant replicates for each treatment. With three humidities, a total of 90 plants were used in the experiment.

After pruning and root-wrapping, all plants were moved on June 1, 1958 from common storage at the horticulture farm to refrigerated storage in the horticulture building basement. One week later, 30 plants were selected at random for each of the three treatments and the treatments applied. The "cream wax" came from the same lot as that used in the field experiment the year before. The hot water treatment consisted of dipping the tops in tap water at the same temperature and for the same length of time as the wax. Both wax and water containers were of identical size and shape immersed in a common electrically heated oil bath. Waxing temperature was 86.0°C or 186.8°F. After treatment all plants were returned to cold storage. On June 16, ten plants were selected at random from each treatment and placed in each controlled humidity cabinet. In order to avoid any possible effect of location within the humidity cabinets, the plants of all three treatments were intermixed.

The temperature the first week of storage was maintained at 45°F. At this temperature shoot growth was almost completely inhibited, which is in accord with the results of Yerkes and Gardner (1934). The temperature was then raised to 60°F, at which temperature shoots developed relatively rapidly, especially in the waxed plants. At the end of two weeks at the higher temperature, the thermostat was again changed to maintain the temperature at 45°F.

Since all three humidity cabinets were within the same temperature-controlled space, all plants were subjected to the same temperature at any given time. Treatment differences therefore can be ascribed only to effects of waxing and hot water treatment, and to storage humidity.

Experimental Design

The experiment was set up as a two-factor completely randomized design. One factor was the humidities and the other factor was the waxing and hot water treatment versus the untreated. With three humidities and three treatments, there were a total of nine treatment combinations.

Space was available for only ten plants of each treatment combination so they were regarded as single-plant replicates and randomized on the same basis in order to obtain the maximum number of degrees of freedom for statistical analysis.

Treatment of data was by analysis of variance. Original data were used for analysis in all measurements except one, where the data were reduced to percentages. Here the variances differed considerably between treatments, and conversion of the values to angles whose sine is the square root of the percentage was found to provide a more valid test.

Results

Shoot number

Four weeks after the plants were placed in the humidity cabinets, the new shoot number and length were counted and measured. Table 10 gives the mean number of shoots per plant and an overall analysis of variance. Shoot length was measured in centimeters rather than inches because the smaller units provided a greater degree of accuracy for the amount of growth concerned. Measurements were recorded to the nearest centimeter, and consequently any growth of less than one-half centimeter was not counted.

The analysis of variance shows that the combined effects of wax and hot water treatments were highly significant, but effects of humidity differences were not significant. Inspection of the table of treatment means shows that nearly all of the treatment effects were due to the waxing, the number of new shoots being about two and one half times that of either the hot water treated or the untreated. The hot water treatment does not appear to differ significantly from the un-

Table 10. Shoot number per plant

	Relative humidity 100%	75%	50%	Totals
Waxed	17.4[a]	17.2	15.4	50.0
Hot water	8.4	5.6	6.5	20.5
Untreated	7.4	5.2	5.2	17.8
Totals	33.2	28.0	27.1	

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	89	4471.789		
Treat. comb.	8	2224.489	278.061	10.022**
Wax and H.W.	2	2127.089	1063.544	38.334**
Humidity	2	72.2889	36.1444	1.303
Interaction	4	25.1111	6.2777	0.226
Error	81	2247.30	27.7444	

[a]Treatment means.

**Significant at the 1% level.

treated, but the true effects of the hot water are masked by the fact that some of the cane length was injured and the number of new shoots per unit length of cane was actually higher than the untreated.

Although the analysis of variance does not show a significant effect of humidities, the table of treatment means, nevertheless shows a general trend toward fewer new shoots at the lower humidities. One reason why the overall differences are not significant is that the differences are less in the waxed treatment, but the totals are so much larger than the other treatments that they overshadow the greater differences between humidities for the hot water treatment and the untreated. The differences due to humidity in the waxed treatment would be expected to be less because of the moisture barrier effect of the wax. Another reason why humidity differences are small, is that the plants had been in storage only four weeks and the canes may not have reached equilibrium with the storage humidity. Also, the amount of moisture in the root wrap was at its highest level and moisture could easily move upward to replace that lost by the canes at the lower humidities.

New shoot length

Table 11 lists the total length of new growth per plant in centimeters and an overall analysis of variance of the data. As in number of new shoots, the effects of waxing and hot water treatment are highly significant but the effects of humidity are not. The reasons for this response are much the same as for number of new shoots, namely that the large means for the waxed, where differences would be expected to be less, outweigh the larger differences in the smaller means.

Of special interest is the fact that there was on the average almost twice as much total growth in the hot water treated as in the untreated. The difference is the greatest at the lowest humidity. One possible explanation for this is that the hot water injured some of the cane tips and most of

Table 11. Total shoot length per plant in centimeters

	Relative humidity 100%	75%	50%	Totals
Waxed	145.2[a]	158.4	157.5	461.1
Hot water	41.0	44.1	45.2	130.3
Untreated	40.5	17.1	16.0	73.6
Totals	226.7	219.6	218.7	

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	89	436356.89		
Treat. comb.	8	297012.49	37126.56	23.250**
Wax and H.W.	2	291999.75	145999.87	91.430**
Humidity	2	128.02	64.010	0.040
Interaction	4	4884.72	1221.180	0.765
Error	81	129344.40	1596.84	

[a]Treatment means.

**Significant at the 1% level.

the growth was from buds originating near the bud union where they were closer to the moisture supply in the root wrap. The fact that total shoot growth for the untreated in the 100 per cent humidity cabinet was about the same as the hot water treated in the same humidity tends to support this hypothesis.

The most important effect noted in this measurement is the great difference in shoot growth between the waxed and the untreated. On the average, the waxed plants produced more than six times the new growth of the untreated. This confirms the observation made the previous year on plants prepared for the field experiment. The reason or reasons for this great difference in response is somewhat difficult to resolve. If it were a moisture barrier effect of the wax, one might not expect to find the great difference there is in the 100 per cent humidity, although the difference here does appear to be slightly less than in the lower humidities. If it were due to a stimulatory effect of the waxing temperature, then the hot water treatment might have been expected to produce similar results, which it did not.

Mold growth

By the time eight weeks had elapsed after the storage experiment was begun, considerable mold growth had developed on the distal portions of some canes. Practically all of this mold was on cane segments that were dead. Since there were obvious differences in degrees of mold development between the various treatments, the amount of mold on each plant was estimated and recorded.

The method of evaluating the mold was by ranking. A range of one to four was set up, with one equal to no visible mold and four equal to heavy mold infestation. Evaluation was roughly on the basis of per cent of cane surface covered by molds. The maximum was about 25 per cent.

Table 12 presents the treatment means and analysis of variance for this measurement. It is interesting to note that there were highly significant differences in moldiness for

Table 12. Mold growth by ranks[a]

	Relative humidity			Totals
	100%	75%	50%	
Waxed	1.5[b]	1.6	1.2	4.3
Hot water	2.9	2.7	2.4	8.0
Untreated	2.5	2.2	1.2	5.9
Totals	6.9	6.5	4.8	

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	89	81.956		
Treat. Comb.	8	34.356	4.294	7.308**
Wax and H.W.	2	22.956	11.478	19.532**
Humidities	2	8.289	4.144	7.053**
Interaction	4	3.111	0.778	1.324
Error	81	47.600	0.58765	

[a]Key to ranks: 1 - no mold growth; 2 - little mold growth, up to 10 per cent of cane affected; 3 - moderately moldy, 10 to 20 per cent of cane affected; 4 - heavy mold infestation, more than 20 per cent of cane affected.

[b]Treatment means.

**Significant at 1% level.

both the wax and hot water treatments and for the humidities.

The treatment means show there is a general trend toward less mold development in the direction of low humidity for all three treatments. This might be expected because fungi in general develop slower at lower humidities.

The average for the waxed treatment is appreciably less than for the untreated, the difference being the greatest at the highest humidity where the untreated became very moldy.

This confirms observations made by Neilson (1931b) on the effect of wax in reducing mold development on roses.

Of particular interest is the fact that the plants receiving the hot water treatment were considerably more affected by mold than either the waxed or the untreated. This apparently lies in the fact that the hot water treatment injured some of the cane tissue, thus providing a better substrate for saprophytic molds.

Although the waxed roses were significantly less moldy than the other treatments, there was nevertheless a small amount of mold developing. Close examination of the waxed canes indicates that the mold grows through small imperfections in the wax coating, such as abraded areas and ruptured air bubbles. The feeding hyphae apparently grow in the substrate beneath the wax and the fruiting structures above. From this it appears that one of the reasons for the reduction of mold by the wax may be the mechanical obstruction to hyphal penetration.

Dieback

At the time the plants were evaluated for mold development, the amount of dieback of cane was also recorded. The method was to measure the total length of dead cane on a given plant and to compare this with the total original cane length. By dividing the original cane length into the total length dead, the percentage of cane length dead was obtained for each plant.

Table 13 lists the treatment means and gives the overall analysis of variance. The trends in humidity effects are not all in the same direction. For the waxed and hot water treatment, the amount of dieback increases as the storage humidity drops, compared to the reverse for the untreated plants. This is also the reason why the overall effects of humidity were not significant. The opposite trends tended to cancel each

Table 13. Per cent cane length dead, overall analysis

	Relative humidity			Totals
	100%	75%	50%	
Waxed	11.4	13.3	15.2	39.9
Hot water	33.1	37.6	48.9	119.6
Untreated	23.8	18.9	11.6	54.3
Totals	68.3	69.8	75.7	

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	89	26576.303		
Treat. comb.	8	14180.879	1773.59	11.590**
Wax and H.W.	2	12031.06	6015.53	39.310**
Humidity	2	99.62	49.810	0.325
Interaction	4	2050.20	512.550	3.349*
Error	81	12395.43	153.02987	

*Significant at 5% level.

**Significant at 1% level.

other, resulting in totals for each humidity of about equal magnitude.

Although the overall analysis of variance shows the differences in humidity to be not significant, inspection of the treatment means shows that within each separate treatment there is probably a real difference due to humidities. Accordingly, the treatments were analyzed separately to see if this might be true. Since the effects of both waxing and hot water treatment followed the same trend they were combined in a single analysis of variance as presented in the first part of Table 14. As expected, the effects of the different humidities were significant, although only at the 5 per cent level. Of interest also is the fact that there was no significant interaction, indicating that the effects of humidity operated independently of waxing or hot water treatment and that the differences due to humidity were of the same order of magnitude regardless of treatment.

The second part of Table 14 gives the separate analysis of variance for the untreated plants. Differences in dieback are significant at the 1 per cent level. Thus it is established that there are significant differences in treatment effects due to humidity, but these differences do not vary in the same direction for all treatments.

The overall analysis of variance (Table 13) was made on the original data as percentage values. In the separate

Table 14. Per cent cane length dead, separate analyses

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Analysis of variance of waxed and hot water treatments				
Total	59	11250.73		
Treat. comb.	5	6436.67	1287.33	14.440**
Wax and H.W.	1	5806.78	5806.78	65.135**
Humidities	2	570.40	285.20	3.199*
Interaction	2	59.49	29.74	0.334
Error	54	4814.06	89.14925	
Analysis of variance of untreated				
Total	29	5908.76		
Humidities	2	1995.18	997.590	6.882**
Error	27	3913.58	144.947	

*Significant at the 5% level.

**Significant at the 1% level.

analysis of variance (Table 14), however, it was found that transforming the original data to arcsin values according to the method given in Snedecor (1956, pp. 316-320) gave more valid estimates, particularly in the analysis of variance for the untreated plants. Two reasons for this were the fewer degrees of freedom available and non-homogeneous variances became more prominent when the overall analysis was divided up.

Having shown that the effects of humidity were real, although in different directions for different treatments it remains to be explained why. For the waxed and the hot water treated, the increase in dieback with lowering of humidity may be due to a desiccation effect. If this is the case the increase in dieback would be less in the waxed, which the treatment means seem to indicate. The decrease, however, in dieback with lower humidities of the untreated may be an effect of inhibition of parasitic fungi at the lower humidities. Or looking at it the other way, increasing humidity may have encouraged the growth of parasitic fungi. If this is the situation, the same response would not be expected in the waxed treatments because of the layer of wax. Similarly, the hot water treated plants would not necessarily respond in a like manner, since the hot water treatment might possibly have acted as a sterilant, or the treatment killed much of the soft cane at the distal ends, leaving a larger proportion of more mature tissue near the base of the plant.

The analysis of variance and the treatment means also show that there is a significant difference between the waxed, hot water treated and untreated as measured by cane dieback. The smaller amount of dieback in the waxed compared with the untreated can quite reasonably be explained on the basis of both the physical impediment of the wax to fungi, and the moisture barrier effect tending to maintain the waxed canes in a more vigorous condition. The much greater amount of cane dieback in the hot water treated is most probably a direct effect of injury by the hot water. Although both wax and hot water were at the same temperature at the time of treatment, the actual heating effect of each material on the cane may have been quite different. At room temperature, the wax used is a solid, but water at the same temperature is still a liquid. Therefore, when a rose cane at room temperature is immersed in the melted wax the immediate effect is to solidify a layer of wax at the cane surface which might act as a thermal insulator. This would not be true of the water, which remains a liquid. There may also be other factors, such as the differences in wettability between wax and water, heat capacity, heat conductivity, and so forth.

Root growth

After all data on the response of the tops to treatments had been recorded, the root wrapping was removed and the roots examined for new growth. This measurement was necessarily delayed until after all data on the tops had been taken, in order not to alter the effects of treatment by disturbing the root system. This had the disadvantage of not allowing the measurement of new root growth at the same time that new shoots were measured, although it had the advantage that the cumulative effect of the entire storage period could be recorded at one time. There is no doubt, however, that there was appreciable root development concurrent with shoot growth as shown by Figures 1 and 2.

Measurements were based on estimates of the total number of new roots produced. Treatments in which there were no new roots produced within the root pack were given the value of one, while those which contained the heaviest growth were assigned a value of five. Plants which fell in the highest rank and which had the heaviest new root system frequently had as many as 25, five inch new roots. The procedure of five group ranking, as an estimate of treatment effect, has been found valid by Mahlstede and Lana (1958).

The data for root growth are presented in Table 15. Statistical analysis of these data show a highly significant effect for both wax and hot water treatment as well as for humidities. Of particular interest in the table of treatment means is the fact that the waxed plants produced about 50 per cent more new roots than the untreated. This confirms the observations made the previous year on plants used in the field experiment. The effects of hot water treatment were not different from those which were not treated.

Storage humidities had a very noticeable effect on new root production, since in the 100 per cent relative humidity the plants produced about 50 per cent more new roots than those in the 50 per cent relative humidity environment. Since all root wrapping was done at the same time using sphagnum moss from the same lot uniformly mixed, the amount of new root growth must be an effect of top treatment. The exact mechanism of the response remains to be determined. It also ap-

Table 15. Root growth by ranks[a]

	Relative humidity			Totals
	100%	75%	50%	
Waxed	4.4[b]	4.1	3.1	11.6
Hot water	2.9	2.4	1.6	6.9
Untreated	2.9	2.7	1.7	7.3
Totals	10.2	9.2	6.4	

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	89	126.40		
Treat. comb.	8	71.40	8.9250	13.144**
Wax and H.W.	2	45.267	22.6333	33.333**
Humidities	2	25.867	12.9333	19.047**
Interaction	4	0.267	0.0667	0.098
Error	81	55.000	0.67901	

[a]Key to ranks: 1 - no new roots; 2 - few new roots; 3 - moderate root growth; 4 - heavy root growth; 5 - very heavy root growth.

[b]Treatment means.

**Significant at the 1% level.

pears that the effects of waxing and storage humidity are cumulative.

Moisture in canes

In order to follow changes in moisture content in the canes due to treatment and humidity, moisture tests were made on a sample of each treatment beginning August 4th, about 7 weeks after the storage test was begun. A total of five tests were made, the last on August 30. Each test was made on a different plant, with the test sample taken near the center section of a full length, live cane. In testing cane sections of the waxed treatment it was necessary to remove the wax before weighing in order to obtain data comparable with the unwaxed. It was found that cooling the waxed canes to a temperature of about 40°F in a household refrigerator facilitated the removal of the wax. At room temperature, the wax was soft and sticky. Temperatures below freezing were also tried but this made the wax too brittle and it tended to chip rather than peel off in sheets. It was also found that wax removal was easier if the thorns were removed. This was easily accomplished by applying a slight lateral pressure with a fingertip to the thorn. Both the waxed and unwaxed cane sections were treated in as similar a manner as possible in order to minimize errors.

The moisture test method was by drying in a 100°C oven for 24 hours and converting the weight lost to moisture per cent. Results are presented as per cent of fresh weight. Some earlier tests made on drying rates of rose cane sections at 100°C had shown that weight loss ceases at about 12 to 16 hours. It was not necessary therefore, to make check weighings after the 24 hour period.

It was originally intended that a moisture test be made on each individual plant in the experiment, especially since treatment differences might be small. However, it was not possible to obtain equivalent samples from all plants owing to mold and dieback, so after five tests the data were tabulated and subjected to statistical treatment. The treatment and humidity differences were both significant at the 1 per cent level, which made further testing unnecessary.

Table 16 gives the treatment means and the analysis of variance. It is seen that the maximum difference in moisture content is only 7.3 per cent, between the waxed plants stored at the highest humidity and the untreated plants stored at the lowest humidity.

Table 16. Moisture per cent in canes

	Relative humidity			Totals
	100%	75%	50%	
Waxed	58.1[a]	57.7	57.3	173.1
Hot water	57.0	57.7	53.0	167.7
Untreated	54.7	56.0	50.8	161.5
Totals	169.8	171.4	161.1	

Analysis of variance

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Total	44	479.390		
Treat. comb.	8	251.280	31.410	4.957**
Wax and H.W.	2	110.710	55.355	8.736**
Humidities	2	102.830	51.415	8.114**
Interaction	4	37.740	9.435	1.489
Error	36	228.110	6.33638	

[a]Treatment means.

**Significant at the 1% level.

One fact stands out clearly in the treatment means. The waxed plants maintained a high moisture content regardless of storage humidity. Even at 100 per cent relative humidity the waxed plants still had a higher moisture content than the untreated.

Responses of althea (*Hibiscus syriacus*)

Although the thirty rose plants in each humidity cabinet occupied most of the space, it was possible, by careful placement, to put in six additional plants. Therefore, 18 dormant althea bushes were both top and root pruned to about the same dimensions as the rose plants and similarly root wrapped. Six of the plants were waxed (at the same time as the roses), six were dipped in hot water and the remaining six left untreated. They were then divided between the three humidity cabinets so that each cabinet contained two each of the three treatments.

The althea, as expected, was much slower in initiating bud growth. At the end of eight weeks, the maximum length of new shoots was about three inches compared to nine inches for the roses.

Because of the small number of plants in each treatment it was difficult to assess the true effects of treatment. It was quite apparent, however, that the hot water treatment was detrimental because both plants in the lowest relative humidity (50 per cent) cabinet died, and the corresponding treatment in the higher humidities produced noticeably less shoot growth.

The roots were examined, and although there were a few new roots, there did not seem to be any consistent differences between treatments, except for the two plants that died, which of course were without roots.

Although the rose plants in the same cabinet contained various degrees of mold infestation, no mold could be observed on any of the althea, even on the dead wood.

It was concluded from this experiment that: hot water is detrimental compared with waxing at the same temperature; and that the althea is less susceptible to mold than roses.

Discussion

Figure 6 summarizes in graphic form the effects of treatments. It is much easier to visualize the treatment differences here than from tables of figures. Of particular interest are the large differences in shoot number and shoot length compared with the small differences in moisture content. It is also noted that most measurements follow the same trend, namely a smaller response at the lower humidities, with one notable exception. In the hot water treated plants the per cent cane length dead increased with decreasing humidity. This may be a desiccation effect, possibly resulting from

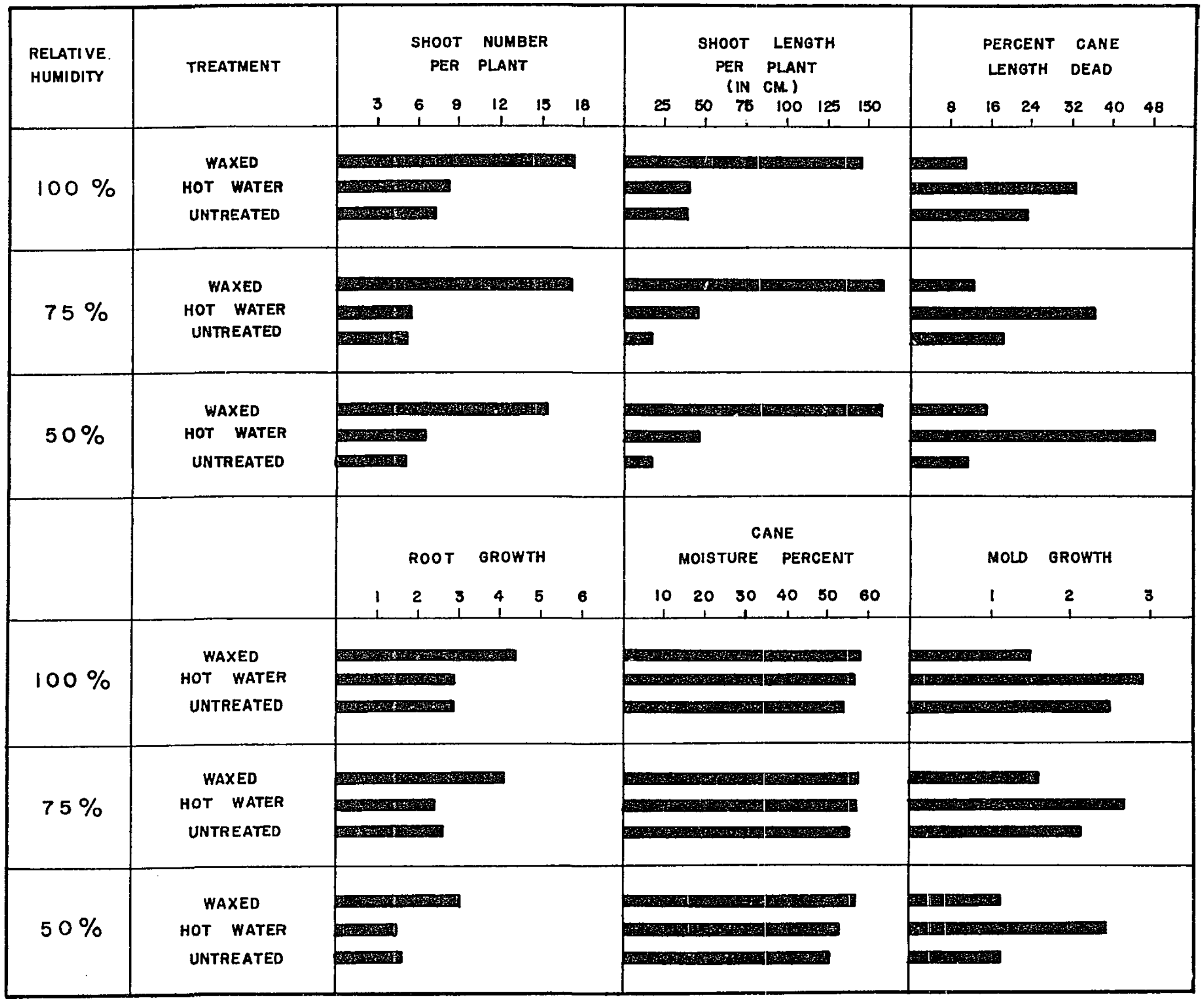


FIGURE 6. GRAPHIC SUMMARY OF CONTROLLED HUMIDITY STORAGE EXPERIMENT

injury to the water translocation system by the hot water treatment.

The data of the althea test were not presented because of the small numbers of plants used. Nevertheless, there is an indication that compared with althea, roses are much more susceptible to mold and dieback under the same conditions. Since waxing significantly reduced mold and dieback on the roses, it provides further evidence of why roses are the principal ornamental being commercially waxed.

The controlled humidity experiment shows that there is some stimulating effect on both bud and root growth by the waxes. Whether or not this effect is mainly responsible for the increased growth of waxed plants in the field is not known. It does seem reasonable to suppose, though, that since the waxes do have the effect of stimulating root growth, they may at least help the plant to recover faster immediately after planting. This stimulatory effect seems to be independent of any moisture barrier effect of the wax because both shoot growth and root growth were significantly greater even in the 100 per cent relative humidity environment where desiccation was not a problem.

The nature of the stimulatory effect of the waxing is not clear. The results reported here on the effects of waxing temperatures alone by using hot water were not conclusive, primarily because water at the same temperature as the wax was apparently injurious. Because of differences in freezing points, viscosity, and heat conductivity, between wax and water, it may be interesting to test the effects of hot water using temperatures somewhat lower than those normally used for waxing roses. Or perhaps some other method can be found for subjecting the rose canes to temperatures similar to those during waxing. Waxing the canes as usual and then removing the wax was considered, but this is impractical because of the great difficulty in removing the wax. There is also the possibility that the wax may have some chemical effect independent of temperature.

Regardless of the direct effect of waxing on the buds, the fact that root growth is also stimulated points toward the possibility that some hormone process may be involved. There is no direct contact of the root system with the wax, and root moistures are not a factor because all plants were root-wrapped with sphagnum moss from a common lot. It might be supposed that the unwaxed plants would lose more moisture from the canes and thereby draw upon the moisture supply in the root wrap, but the root-stimulating effect is just as great under conditions of 100 per cent relative humidity where there is little or no loss of moisture from unwaxed canes.

The principal effects of long storage were mold and die-back. The two effects are related insofar as practically all of the mold was on dead cane. It is possible, of course, that the same molds may be the cause of the dieback rather than developing saprophytically after the cane tissues died. In either case, it is clear that the waxing reduced both the amount of dieback and the amount of mold, especially at the higher humidities where molds normally grow better.

DESICCATION EXPERIMENT

Purpose

Since the field experiment had proven the paraffin wax to be beneficial to growth and flower production, the next problem was to determine the reason. It had long been assumed that the protective effect of the wax was primarily due to its impermeability to moisture, and that plant material covered with it therefore does not dry out as rapidly as similar material not covered. In the case of roses at least, this has not been definitely proven.

Literature

The only data that can be found in the literature on the retardation of moisture loss in woody plant material by paraffin wax are in a short table of figures by Neilson (1931b), showing that weight loss is reduced considerably in willow sticks by a coating of hot paraffin.

Shelton (1938) tested paraffin wax and various wax mixtures using "gelatin candles" to simulate the shape of plant stems and found that paraffin considerably retarded moisture loss. He was interested mainly in the physical properties of the wax with regard to moisture impermeability and did not test the wax on plant material. His work is useful, however, in that it showed that the wax does reduce moisture loss under conditions simulating plant material but without the complicating factors associated with active living tissues.

Materials and Method

To investigate the assumption that a coating of paraffin wax retards moisture loss in rose canes, an experiment was set up in the laboratory using live rose canes.

One cane was cut from each of five dormant rose bushes. Each cane in turn was trimmed to a length of nine inches and then cut into three sections of three inches each. The three, three-inch pieces from each cane were then distributed at random among three groups for treatment. The first group was dipped and completely covered with wax, the ends only of the second group were dipped in wax, and the third group was left untreated.

Since roses are the only kind of plant still waxed in quantity by nurserymen, it was thought that possibly this was because roses tend to lose moisture more rapidly than other woody plant materials. Therefore some stems of althea (*Hibiscus syriacus*) and privet (*Ligustrum amurense*) were obtained and prepared for the test in exactly the same way as the roses. For several weeks prior to the test, all three species had been stored together in the same underground common storage at the horticulture farm, so they were all in equilibrium with the same atmospheric humidity.

In order to assure that the samples of all three species would present the same amount of exposed surface, stems of approximately one-fourth inch diameter were selected. Also, all stems were of one year old wood.

Following treatment, all specimens were arranged on a sheet of glass and left exposed to the laboratory atmosphere. Periodically, the glass plate was moved or rotated to avoid possible biasing effects of uneven room air currents or uneven exposure to sources of radiated heat. The glass plate was used as a support to insure that all moisture lost was by evaporation only, and to avoid contact with other materials that might also contain moisture.

The wax used was the "cream wax" from the same lot as that used in the field experiment the preceding year. The "green wax" was not tested since its effects, as shown by the field test, were the same as the "cream wax". The wax was melted in a small thermostatically controlled electric water bath heater. Temperature of the wax was 85.0°C (185.0°F) which was the maximum temperature to which the heater could be adjusted.

Before waxing, all specimens were individually weighed on a balance to three significant figures. After waxing, the specimens were again weighed and the increase recorded as the weight of wax. All subsequent calculations of weight loss or per cent moisture loss are based on the weight of the unwaxed specimen. For the first few days, weighings were made every 24 hours. The data were converted to give per cent weight loss based on an original weight of 100 per cent, and plotted on cross-section paper to produce a set of curves.

The relative humidity of the laboratory atmosphere was measured at the time of the weighings by a motor driven wet and dry bulb psychrometer. Laboratory temperatures were also obtained in the process. The relative humidity during the experiment ranged from 38 per cent to 74 per cent and the temperature varied between 68.0 and 78.5°F.

Results and Discussion

Data obtained from the experiment are plotted in Figure 7. Loss in weight is assumed to be entirely that of moisture evaporation. A small amount of weight loss might be expected from respiration but that is probably quite negligible.

The sets of curves show that the untreated groups of all three species lost weight very rapidly, coming to equilibrium with the laboratory humidity at the end of about four days. Coating the ends of the stem sections had a large effect on the althea, a smaller effect on the privet, but almost no effect on the rose. Considerably less moisture was lost from the althea merely by waxing the cut ends. This indicates that most of the evaporation took place from the ends and relative-

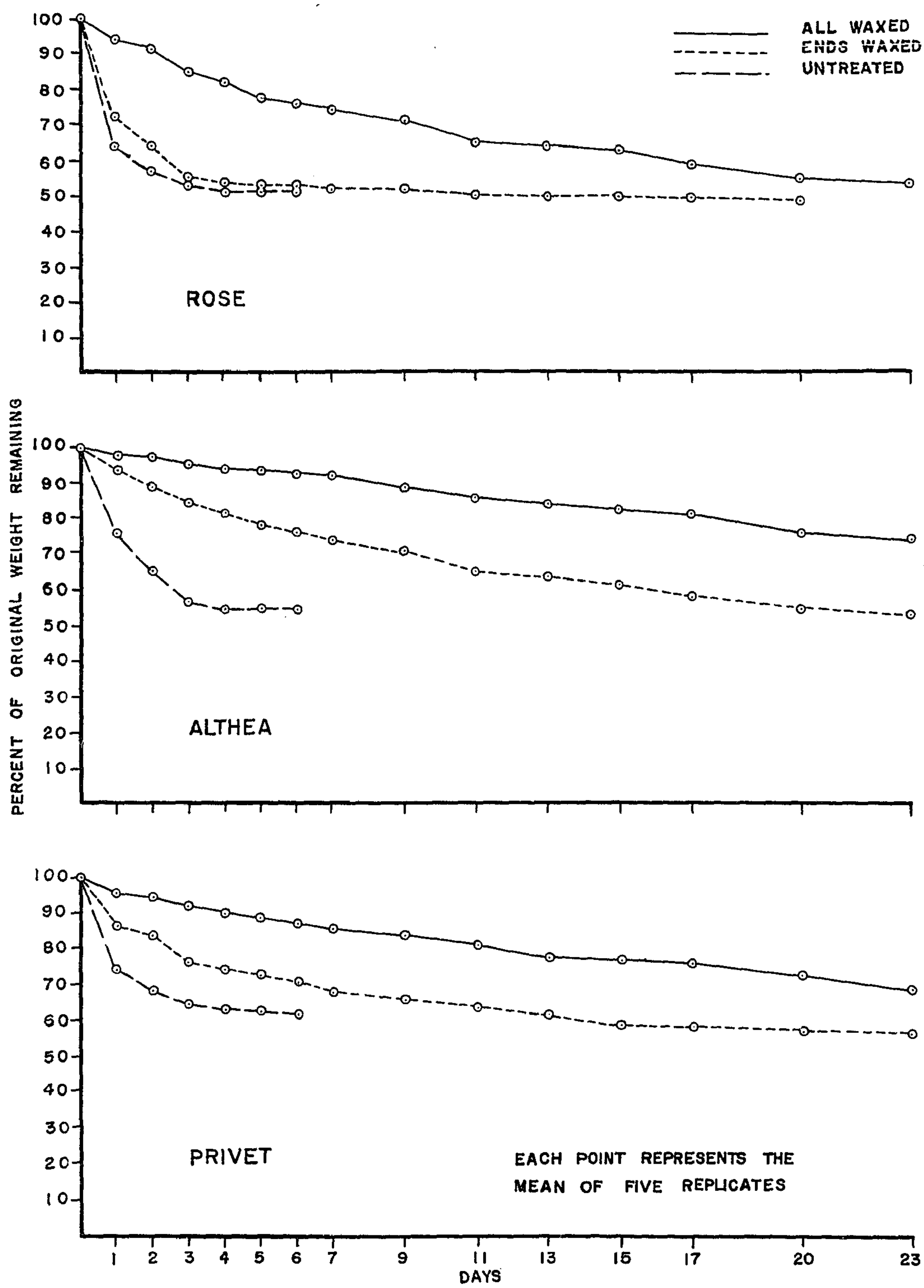


FIGURE 7. LOSS IN WEIGHT OF TREATED STEM SECTIONS

ly little from the sides. In the rose, waxing the cut ends failed to reduce moisture loss appreciably. This indicates that most of the evaporation must be directly through the sides of the canes. The response of privet to the waxing of the ends was intermediate between those of the rose and althea. From these observations it is not difficult to understand why roses continue to be waxed by nurserymen while most other woody plants are not.

Since the two curves, ends waxed and untreated, for the rose were so close together, it was interesting to see if the slight reduction in moisture loss from waxing the ends might not be due simply to a reduction of exposed surface. Accordingly, the proportion of waxed surface was calculated, based on the entire end surface being covered plus one-eighth of an inch of the sides. The results showed that about 8.33 per cent of the total surface was covered with wax. Since the reduction in moisture loss the first two days was only slightly higher than this, it indicates that evaporation through the normal surface of the cane is almost as high as that from a freshly cut end surface.

The curve for the completely waxed stem sections for the rose shows the value of waxing, at least with respect to retarding desiccation. By coating the entire surface, moisture loss did not reach equilibrium with the atmosphere even at the end of 23 days. This compares with almost complete loss of moisture at the end of 4 days without the wax.

It is noted that the completely waxed rose stem section lost moisture appreciably faster than the corresponding treatment for the althea and privet. This is due, no doubt, to the greater natural protection possessed by the latter, and further points up why the rose is more benefited by the waxing.

It is interesting to note that the curve for the completely waxed rose stem sections almost exactly coincides with that for waxing of the cut ends only of althea. This indicates that the natural protection of the althea is as effective as that of a layer of paraffin wax applied to the rose. Or looking at it another way, it would be necessary to coat the canes of roses with a layer of paraffin in order to reduce the loss of moisture to the same rate as that of some other woody plants without the wax.

RESPIRATION EXPERIMENTS

Purpose

The field experiment showed that the application of paraffin wax to roses results in increased growth and flower production and the laboratory experiment on moisture loss indicated that one beneficial effect of waxing is the reduction of moisture evaporation. The controlled humidity experiment showed that the wax also causes increased root growth, which appears to be a physiological effect. The possible effect of paraffin wax on respiration has been mentioned by early experimenters but has not actually been measured. Since gas exchange might provide a clue to internal processes, it was thought desirable to experimentally determine what effects the wax might have on respiration.

Literature

Morris in 1921 (p. 96), in his discussion of covering the entire scion of a graft with wax writes:

> In the epidermis of all parts of the plant which are exposed to the air are minute openings called stomata, in addition to the larger lenticels. It is the knowledge of this fact perhaps that has prevented botanists and horticulturists in the past from covering a graft completely with a material that is impervious to air and moisture. In actual practice I have found that this interference with respiration of the graft is not of practical importance. The respiration of the stock attends to the matter of metabolism and the scion is taken care of. Reparative and nutrient materials together with enzymes for

> stimulating growth are sent into the scion from the stock irrespective of interference with respiration of the scion itself.

Although Morris' statements are little more than speculation he does show that covering the entire scion with wax does not harm the scion, regardless of the real effects on respiration.

Neilson (1931b) in listing some of the effects of waxing nursery stock states:

> Insofar as can be determined from observation on a large number of plants, in storage or after planting, there do not appear to be any injurious effects from the wax checking respiration. It is believed that there are enough minute openings in the wax to permit the escape of any respiration products that might be injurious.

Here again the author is somewhat speculative. No actual evidence is presented to show any relationship of waxing to true respiration. He does point out, however, that covering the entire plant top with wax is not injurious, whatever the real effect on respiration.

In 1924, Magness and Diehl studied respiration of apple fruits coated with paraffin and with oil. They concluded that "respiration was markedly reduced by the coatings." The paraffin was applied by wiping on as a solution in a volatile solvent. What effect the solvent might have had is not known, and presumably the paraffin layer must have been quite thin. Also the coating was applied at room temperature, so the effects might not be the same as wax applied as a hot dip.

Bose and Basu (1954) studied the effects of coating mango fruits with paraffin. The mangos were dipped in melted paraffin at 176°F for 10 seconds, and in a 50 per cent solution of paraffin in petroleum ether at 77°F for 10 seconds. They found that respiration intensity was reduced by the paraffin coating. At 37°C (98.6°F) respiration was 2.2 mgm CO_2/hr./kg. for hot paraffin dipped, 8.04 for paraffin applied as a solution, and 9.70 for the untreated fruit.

Materials and Method

Measurement of respiration was by periodic determinations of carbon dioxide and oxygen concentration, produced by sections of variously treated live rose canes in sealed flasks. Canes were taken from plants that had been in cold storage since the preceding winter. The flasks used were 1,000 ml. Erlenmeyer type specially modified to permit sealing of the rubber stopper with a layer of mercury. A description and diagrammatic illustration of the flask and connecting tubes appears in a paper by Ragai and Loomis (1954). Measurements were made with a Haldane gas analyzer. For all except the first experiment reported here, all flasks were kept in an incubator maintained at 27°C.

A preliminary run was made to determine the approximate rates of respiration. From this it was calculated that about 25 grams of fresh rose cane should be used for 1,000 ml.

flasks, to permit adequate changes in gas concentrations in intervals of 12 hours.

Calculations of per cent carbon dioxide and oxygen and respiration rates were by the method given in Loomis and Shull, pp. 144-146 (1939). Respiration rates given as ml. CO_2/ gm dry wt/day are based on average rates to 36 hours, which is the point at which rates begin to deviate from linearity. Volumes were corrected to standard conditions. Corrections were also made for slight differences in sample weights, and dry weights were obtained by drying parallel samples of canes in a 100°C oven for 24 hours.

Rose cane treatments tested were: completely waxed, waxed but with wax removed, dipped in hot water at the same temperature as the wax, and untreated. Cane sections were two and one half to three inches in length. For each experiment, one flask was used for each treatment, but the rose material was taken from several plants and each original cane cut into sections and distributed systematically among the various treatments in order to insure that each treatment would have a composite sample of the same origin and about the same size.

Wax and hot water treatments were with "cream" wax and with distilled water, using a small thermostatically controlled electric water bath heater. On the treatment with wax removed, it was found that wax removal was facilitated by cooling the specimens to about 40°F in a household type refrigerator and by also breaking off the thorns. Other treatments were handled similarly in order to maintain all conditions constant except the one under study.

Results

Experiment 1

Figure 8 shows the changes in respiration rates as indicated by carbon dioxide evolved and oxygen consumed. Respiration rates are substantially constant up to about 10 per cent carbon dioxide, and then begin to slow down. This slowing may be due to one or more of several factors, as for example: depletion of substrate, increase in carbon dioxide concentration, and/or depletion of oxygen. The experiment was continued to seven and one half days to follow changes over as long a period as possible. The curves show that respiration continues, although at a reduced rate, even when the oxygen level reaches a low of three per cent.

The changes in oxygen concentration follow a very close inverse relationship to carbon dioxide. It is not possible to deduce from this whether respiration is limited by oxygen availability or by increasing carbon dioxide concentration. Respiratory quotients (ratio of CO_2 produced to O_2 consumed) were calculated for all measurements (Table 17) but were not significantly different between treatments, indicating that

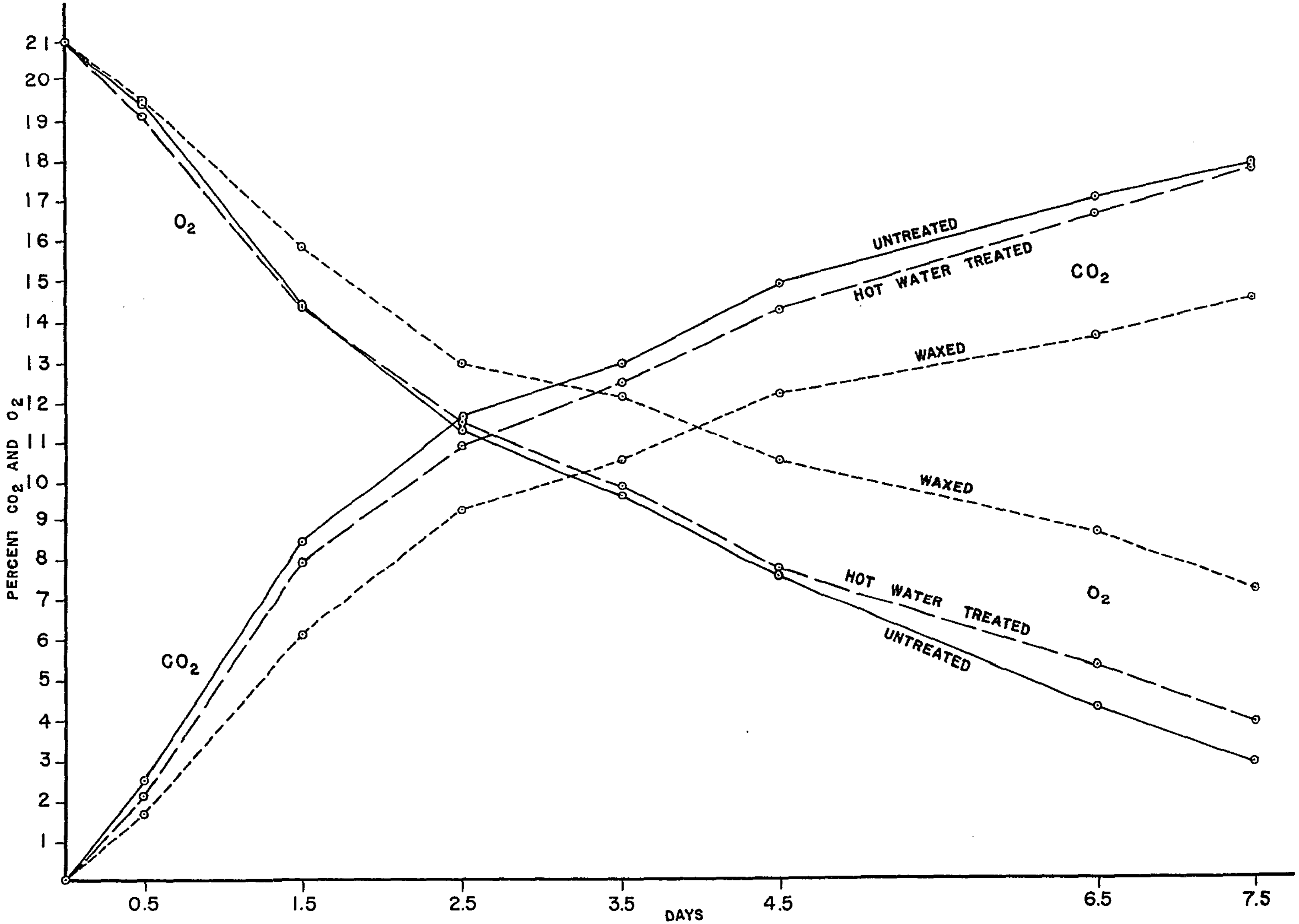


FIGURE 8. EFFECTS OF CANE TREATMENT ON RESPIRATION, EXPERIMENT I

Table 17. Respiratory quotients of treated rose canes

Experiment	Treatment			
	Untreated	Hot water	Waxed	Wax removed
1	1.38	1.32	1.31	
2a	1.38	1.34	1.32	1.30
2b	1.13	1.09	1.09	1.00
3	1.21	1.20	1.09	1.23
	27°C water	70°C water	80°C water	90°C water
4	1.24	1.21	1.26	1.17

the respiratory process must have been similar for all treatments.

The most important result of the experiment is the fact that respiration of the waxed cane sections was about 20 per cent slower than the untreated. This difference was fairly constant throughout the experiment. As indicated by per cent carbon dioxide at each measurement, the waxed canes respired at 72 to 83 per cent of the rate of the untreated.

The effect of hot water treatment is a slight reduction in respiration rate compared with the untreated. The difference is small, but as measured by CO_2 production, appears to be significant.

Experiment 2

Although Experiment 1 clearly showed a difference in respiration between waxed and unwaxed cane sections, previous experiments had shown that hot water the same temperature as the wax may be injurious. Therefore, it was difficult to determine if the differences in respiration rate between the waxed and hot water treated canes were due solely to the gas barrier effect of the wax. Another experiment was therefore set up with an additional treatment in which the canes were waxed but the wax immediately removed.

Figure 9 (Experiment 2a) shows that the treatment with wax removed respired at a rate even higher than the untreated, although the treatment with the wax left on the cane still shows the same retarding effect on respiration as in Experiment 1. It appears from this that the principal effect of the wax itself was that of a barrier to gas exchange, but the process of applying the wax actually increased the respiration rate of the tissues.

The respiratory rate for the hot water treatment is higher than for the untreated. This contrasts with Experiment 1 where the hot water treated material respired at a lower rate than the untreated. The reason for this difference in response is not clear. Possibly, it may be due to a small difference in treatment temperature, as the temperature for this experiment was 82°C compared with 85°C for Experiment 1.

These experiments so far have measured respiration rates immediately after treatment. Since waxes are normally left on the canes for long periods of time it was thought desirable

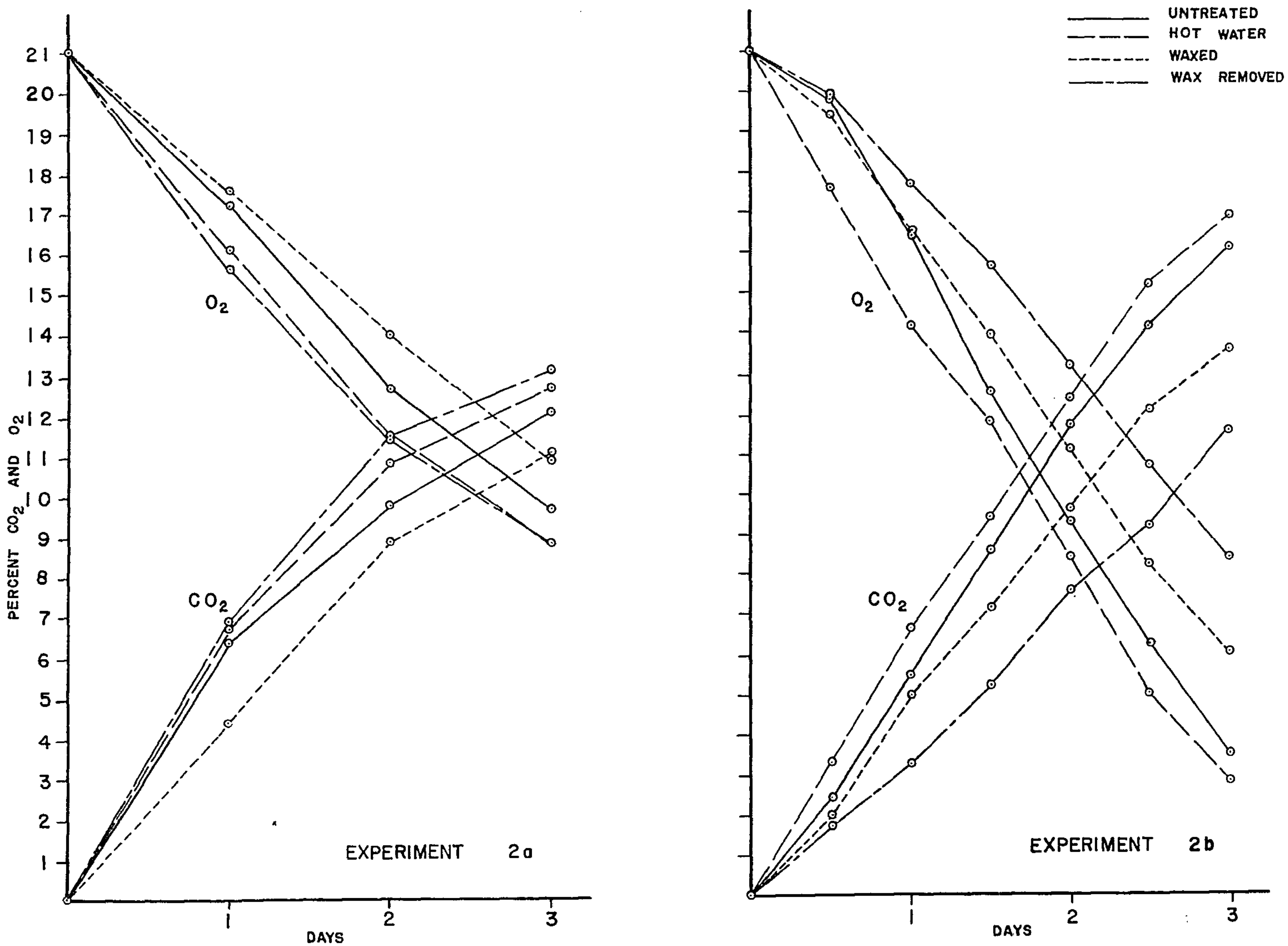


FIGURE 9. EFFECTS OF CANE TREATMENT ON RESPIRATION, EXPERIMENT 2a AND 2b

to measure the respiration rates on the same material at some later date to see if there may be continued differences. Accordingly, the flasks were unsealed and flushed with air so that respiration could continue for a time at normal atmospheric concentrations of carbon dioxide and oxygen. The flasks were connected in series with rubber tubing, and twice a day for about one hour, saturated air was drawn through the system by a water faucet aspirator. After four days, it was noticed that some mold growth was developing, so the flasks were again sealed for respiration measurements. After resealing, all flasks were tested to insure that there was no residual carbon dioxide.

Figure 9 (Experiment 2b) shows the respiration rates for the second set of measurements. Differences were the same as in the first measurements with one exception, that is, the rates for the treatment with wax removed were now the lowest instead of the highest. The reason for this is not clear but it may be due to rapid exhaustion of substrate or other respiratory factors during the preceding period. If this were the case, however, a similar response might have been expected of the hot water treatment, although this did not occur. It was observed that the cane sections that received the hot water treatment had considerably more mold. Measurements on this effect were taken and are listed in Table 18, together with per cent of cane showing dead surface tissue. The fig-

Table 18. Per cent of cane covered by mold and per cent dead, Experiment 2b

	Treatment			
	Untreated	Hot water	Waxed	Wax removed
Per cent mold	20.0	47.5	7.5	5.0
Per cent dead	35.0	62.5	25.0	20.0

ures show that the hot water treatment had more than twice the visible mold as on the untreated and almost ten times as much as the treatment with wax removed. From this it appears that at least part of the explanation of the continued high respiration rate for the hot water treatment may be the respiration of the mold.

It is significant that the respiration rate of the waxed canes remains consistently lower than that of the untreated specimens.

Experiment 3

The two preceding experiments had been carried out with canes treated shortly before respiration rates were measured. In order to determine if the effects of treatments made a relatively long time before measurement had any influence on the results, another experiment was set up using canes from the 100 per cent relative humidity storage cabinet of the controlled humidity experiment. These canes had been treated about three months earlier.

Results are shown in Figure 10. The waxed treatments again respire at a lower rate compared with the untreated. With wax removed from the waxed canes, respiration rate was higher than the group with wax left on, but lower than the untreated. The fact that the wax was in contact with the canes for a long period of time and its removal still resulted in a higher rate of respiration is a good indication that the wax acts mainly as a physical barrier to gas exchange.

The respiration rate for the hot water treatment was higher than for the untreated. Considering that the treatment was applied three months earlier, the effect must be permanent. One permanent effect is injury to the epidermis and some of the cortical cells. What relation this might have with increased respiration rate so long after treatment is not clear. Possibly the cuticle and epidermis are disrupted enough to permit more rapid gas exchange by underlying tissues.

Experiment 4

In the preceding respiration experiments the respiration rates of the hot water treated canes were close to the rates of the untreated, although either consistently higher or consistently lower. Although treatment temperatures were approximately the same for all experiments, a study of the

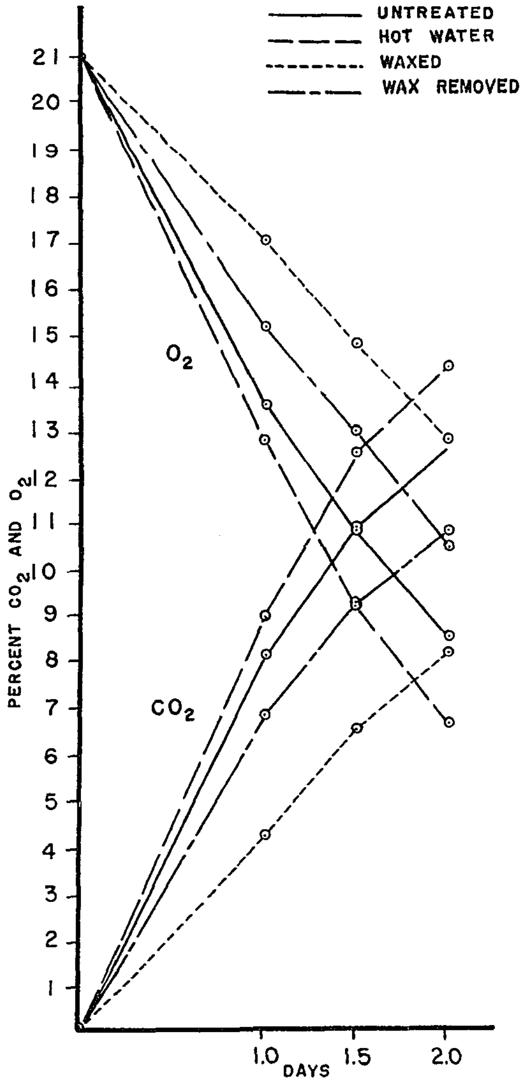


FIGURE 10. EFFECTS OF CANE TREATMENT ON RESPIRATION, EXPERIMENT 3

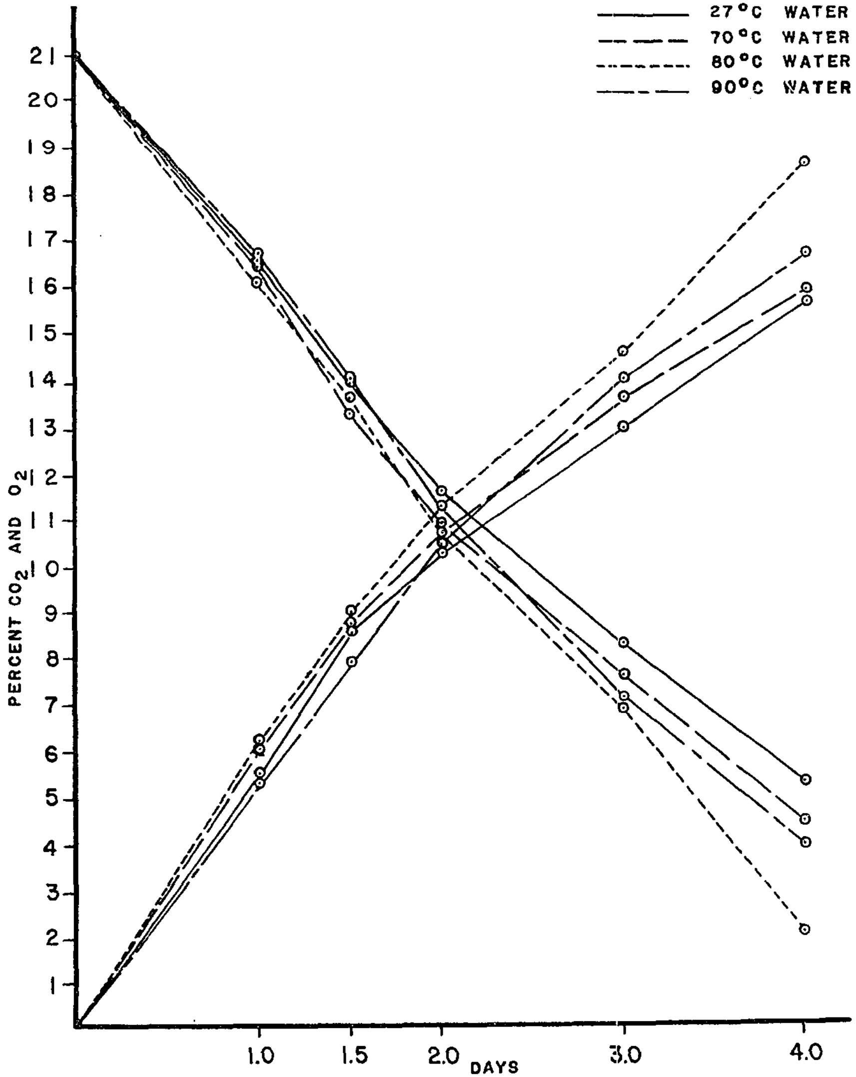


FIGURE 11. EFFECTS OF CANE TREATMENT ON RESPIRATION, EXPERIMENT 4

original data indicated that some small temperature differences may be related to the differences in response. In Experiment 1, the treatment temperature was 85°C and the respiration rate was lower than the untreated. In Experiment 2, the temperature was 82°C, but the respiration rate was higher. In the first part of Experiment 2, the treatment with the wax removed also respired at a higher rate than the untreated. This suggested that there is a stimulatory effect of temperatures below a certain point but a depressing effect above that temperature. Another experiment was therefore arranged to investigate this hypothesis.

Treatments compared were dipping of the canes in water at 27, 70, 80, and 90°C for about two seconds. The 27°C treatment is regarded as untreated, with respect to temperature, as the purpose was to wet the canes the same as in the other treatments.

The data are plotted in Figure 11. For the first 1.5 days the canes dipped in water at 90°C respired at a lower rate than those dipped at 27°C, but the 70 and 80°C treatments respired at a higher rate. Although the differences were small they were consistent. In general these results agree with those of Experiments 1 and 2. It appears that treatment temperatures of 70 to 82°C increase the respiration rate and temperatures of 85°C or above decrease the respiration rate.

Since the differences in respiration rates were relatively small, the experiment was continued beyond 1.5 days in order to follow further changes. At 2.0 days the respiration rate of the 90°C treatment began to exceed that of the untreated (27°C) canes. This occurred at the same time that the beginning of mold development was observed in that treatment. A similar increase in respiration was observed for the 80°C treatment beginning at 3.0 days. There is little doubt that the increases in respiration rates are due to the mold. This also indicates that there is injury to the canes at the higher temperatures, for molds generally develop only on dead tissues. This is confirmed by the general appearance of the canes. Some canes changed from a greenish hue to brown, and this effect was more prominent in the canes treated at the higher temperatures. These observations suggest that the decrease in respiration rate following high temperature treatment is due to actual destruction of tissues.

Discussion

The results of Experiments 1, 2, and 3 show there is definitely a reduction in respiration rates for rose canes coated with paraffin wax. What relation this reduction in respiration may have to other responses of the plants is not clear. It might be assumed that a slowing of respiration would tend to conserve food materials, but this also indicates a lower metabolic rate, which seems incompatible with the observed increase in growth of roots and shoots. Further investigations will be necessary to resolve this.

Respiration rates in terms of milliliters of carbon dioxide produced per gram dry weight per day for the first 36 hours were calculated for all experiments and are presented in Table 19. On the average, waxing reduced respiration to

Table 19. Respiration rates of treated rose canes[a]

Experiment	Treatment			
	Untreated	Hot water	Waxed	Wax removed
1	4.7	4.1	3.0	—
2a	3.7	4.2	3.1	4.2
2b	4.0	4.5	3.4	2.4
3	3.9	4.5	2.4	3.3
	27°C water	70°C water	80°C water	90°C water
4	4.4	4.5	4.7	4.1

[a]Ml. CO_2/g dry wt./day based on average rates to 36 hours.

about 75 per cent of that of the untreated canes. Although there are noticeable differences in respiration rates between experiments these are of little significance as they only reflect the differences between groups of rose canes selected for the various experiments. The important comparisons are between the different treatments of the same experiment.

Respiratory quotients, obtained by dividing the number of milliliters of oxygen used into the number of milliliters of carbon dioxide produced, were calculated for all treatments (Table 17). The values listed are the means calculated from all measurements of gas composition made between 1 and 3 days. The data obtained before the end of the first day were not used because the measurement of smaller gas volumes was subject to greater errors. The data obtained after 3 days were not used in calculating the values in the table because there seemed to be slight drop in respiratory quotient after this time. This would tend to reduce the mean respiratory quotient for the experiments carried the longest, and thus make comparisons less reliable.

It is noted that respiratory quotients, on the whole, range between 1.1 and 1.4, excluding Experiment 2b. This means that more moles of carbon dioxide were produced than moles of oxygen consumed. This is true even for the untreated canes, indicating that this may be the normal response under conditions of the experiments.

The respiratory quotient for all treatments of Experiment 2b was lower than the corresponding treatments in the other experiments. This may have been an effect of exhaustion or change of substrate since the measurements were made several days later from the time of sealing of the flasks, compared with the other experiments.

The waxed treatments in general show a slightly smaller respiratory quotient than the untreated. This is probably a temperature effect since the hot water treated canes responded similarly.

Although the results of these experiments showed that waxing reduced respiration in rose canes (Table 19), other conclusions should be drawn with caution. There was no replication in any of the respiration experiments, although great care was taken to maintain all conditions constant except the treatments under study. As in all biological studies, there is a certain amount of variability in the experimental material which may influence the results. Whether or not the reduction of respiration rates of rose canes by waxing is related to the other observed responses is not known. Further experiments of a more refined nature will be necessary to determine the facts.

ANATOMICAL STUDIES

Purpose

Results of the controlled humidity and respiration experiments suggested that rose canes may be injured when they are dipped in hot water at temperatures normally used for waxing. Although there usually were visible signs of changes to the surface of the cane this was not always the case. It was therefore thought that a microscopic study of the cane tissues might yield direct evidence for some of the indirect results of treatment such as increased dieback and changes in respiration rates. Also it was desirable to make a comparative anatomical study of waxed and untreated canes to see if there may be any differences, and to investigate the possibility of penetration by the waxes.

Materials and Method

The rose canes used were for the most part those which had been used in previous experiments on storage and respiration, which included treatments up to 190°F. The reason for this was that any anatomical changes observed could be related directly to other effects.

After some experimentation with sectioning fresh canes, killing fluids, and mounting technique, it was found that the simplest procedure to meet the needs of the problem was to preserve cane sections in 70 per cent ethyl alcohol, section in a hand microtome, dehydrate to absolute alcohol, transfer to xylene, and then mount on a slide with Canada Balsam and a cover glass. The sectioning of fresh canes was not practical because the tissues were too soft and thin sections could not be made. Preservation in 70 per cent alcohol hardened the tissues so they cut more crisply. At first, cane segments were cut with pruning shears but this was found to crush the canes and break away the tissues outside the cambium. The problem was solved by chipping a groove circumferentially around the cane, as suggested by Sass (1951, p. 10), until the cane was cut through. Temporary slides using only water or 70 per cent alcohol were found impractical because of rapid drying out. Transferring to xylene and permanently sealing with Canada Balsam permitted more careful examination and photomicrography.

Results and Discussion

Samples from approximately 25 rose canes were sectioned and examined. From these, several slides were selected for photomicrography and are reproduced as Figures 12 to 17.

In general, there was no discernible anatomical effect from waxing at any of the temperatures used. There was no evidence that there was any gross penetration of the tissues by the wax. In all sections of the waxed canes, the cuticle

Figure 12. Cross section at rose cane, hot water treated

Note that there is little or no definite injury in this specimen. Magnification 100 diameters

Figure 13. Cross section of rose cane, hot water treated

Note the collapse of the epidermis and first few layers of cortical cells into a dense mass. Magnification 100 diameters

Figure 14. Cross section of rose cane, hot water treated

Note the complete collapse of all cells external to the cambium accompanied by shrinking and tearing. Magnification 100 diameters.

Figure 15. Cross section of rose cane, waxed

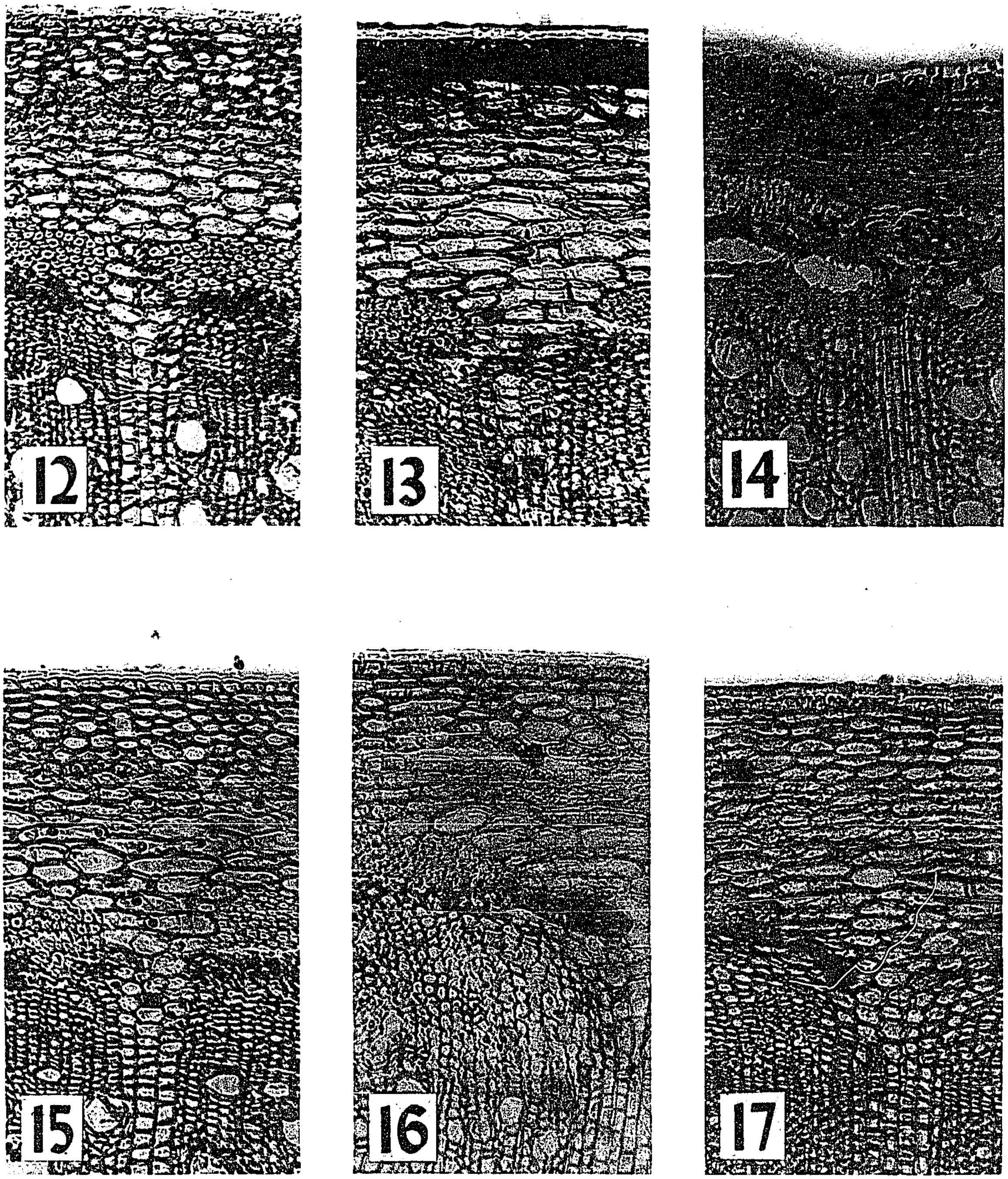
Note that tissues are in normal condition. Magnification 100 diameters

Figure 16. Cross section of rose cane, untreated

Note that tissues are normal. Cracks in cuticle are due to penetration by fungal hyphae. Magnification 100 diameters

Figure 17. Cross section of rose cane, wax removed

Note that tissues are normal. Speckled appearance of epidermis and other tissues due to greater concentration of starch grains in this specimen. Magnification 100 diameters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and epidermis appeared to be intact.

Hot water treatment effects ranged from no apparent injury to complete collapse of all tissues exterior to the central woody cylinder. Figures 12 to 14 show examples of different degrees of injury.

There was no correlation between treatment temperature and the amount of injury. This can undoubtedly be attributed to the variation in time of exposure which varied slightly between canes and between the various segments of the cane.

The cuticle did not appear to be greatly affected by any treatment except where injury to underlying tissues was severe and there was consequently some shrinkage and tearing. The fact that the cuticle was not affected by wax treatment indicates there is little affinity between the cuticle and the wax, which in turn would reduce the possibility of penetration by the wax.

There was no consistent relationship between tissue injury and rate of respiration, as determined by cell plasmolysis. This can probably be attributed to the fact that the amount of tissue affected adversely was relatively small compared with the total mass of the respiring cane. Coating the canes with wax reduced respiration without causing noticeable tissue changes. Dipping the canes in hot water however, increased the respiration rate even though there was some apparent tissue injury.

SUMMARY AND CONCLUSIONS

Summary

Although it has been a practice of nurserymen for more than twenty-five years to protect the canes of dormant rose plants by dipping in melted paraffin wax, the effects of the process have not been critically investigated. A field experiment was carried out in the 1957 growing season using 270 rose plants of the hybrid tea variety Crimson Glory. Treatment included National Wax Company's (Chicago, Illinois) Cream Rosebush Wax and Light Green Rosebush Wax, and an untreated control. Three planting dates were used, which made nine wax by date treatment combinations. A randomized complete block design with six replicates was used. Measurements included: dates of flowering, numbers of flowers, per cent of original cane length surviving, number of new shoots, total length of new growth, weight of roots, number of new roots, number of plants surviving over winter, and number of flowers the second spring. Response of the waxed plants, all measurements considered, was about 50 per cent greater than the untreated. There was no significant difference between the two waxes and responses of both waxed and unwaxed plants were reduced as planting was delayed.

Prior to planting in the field, the waxed plants showed more shoot and root growth than those which were untreated. To evaluate this more precisely, a controlled humidity storage

experiment was set up in the spring of 1958 using relative humidities of 100, 75, and 50 per cent. Temperatures were maintained between 45° and 60°F simultaneously for all humidities. Treatments included plants which were waxed, dipped in hot water the same temperature as the wax, and untreated. The hot water treatment was used to determine the effects of waxing temperatures. Ten plants were used for each of the nine treatment combinations and the experiment was analyzed statistically as a completely randomized design. Data were taken on shoot growth, root growth, mold, dieback, and per cent moisture in canes. Results showed that there was significantly more shoot and root growth on the waxed plants at all humidities, mold development was greater at the higher humidities, dieback was greater in the hot water treated plants and at the lower humidities, and moisture contents of canes were slightly less at the lower humidities, except for the waxed plants.

In order to investigate the effect of paraffin wax as a moisture barrier an experiment making use of stem sections of althea, privet and rose was carried out. Results showed that all unwaxed stems lost substantially all their moisture within four days. If the stem ends were waxed, moisture loss was reduced in althea and privet but not in rose. When entire stem sections were waxed, moisture loss was considerably retarded although it still remained the most rapid in the rose.

Measurements of respiration were made on variously treated cane sections of rose. Waxing reduced respiration about 25 per cent compared with the untreated canes. Waxing the canes, followed by removal of the wax resulted in a higher respiration rate than for the untreated. Hot water treatment at temperatures of 158° to 180°F increased the respiration rate, but the same treatment above 185°F reduced respiration.

An anatomical study of treated rose canes indicated that waxing up to 190°F had no visible effect on any tissue. Dipping in hot water at the same temperature, however, did cause collapse of epidermal, cortical and phloem cells although the cuticle did not appear to be affected. No indications of wax penetration were observed.

Conclusions

1. Dipping dormant rose canes in paraffin waxes increased the field response of the plants as measured by number of flowers and total growth.

2. There was no difference in effects on rose plants between commercial "cream wax" and "green wax".

3. Delayed planting of the roses in the field reduced total response.

4. Number of flowers and total length of new growth gave the best measure of overall effects of the waxes on roses. Number of new shoots and the per cent of original cane living

is highly dependent on the weather for the first several days after planting.

5. A larger proportion of the waxed rose plants survived the winter compared with the unwaxed plants.

6. The beneficial effects of the waxes on roses were apparent the second year, as determined by number of flowers.

7. The waxed packaged roses initiated both shoot and root growth earlier than the unwaxed.

8. Coating rose canes with wax reduced mold development and dieback in storage compared with the unwaxed.

9. Dipping rose canes in hot water at the same temperatures as those used for waxing was injurious, as determined by dieback in storage and by microscopic examination.

10. Waxing maintained a higher moisture content within rose canes, even when stored at 100 per cent relative humidity.

11. Coating rose canes with wax reduced moisture evaporation to less than one-tenth the rate of unwaxed canes.

12. Rose canes without the protection of wax lost moisture very rapidly compared with althea and privet.

13. Respiration of waxed rose canes was reduced to about 75 per cent of the rate of untreated canes.

14. Treatment of rose canes at waxing temperatures by dipping in hot water or by waxing followed by removal of the wax increased respiration rates compared with untreated canes.

15. There was no penetration of rose canes by paraffin wax under ordinary waxing conditions.

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